PRINTED ON THIN PAPER FOR FOREIGN CIRCULATION

GENERAL LIBRARY JUN 9 1920 UNIV. OF MICH.

ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND ALEX. RICHARDSON.

OFFICES FOR ADVERTISEMENTS AND PUBLICATION, 35 & 36, BEDFORD STREET, STRAND, LONDON, W.C. 2

VOL. CIX.—No. 2838.] LONDON: FRIDAY, MAY 21, 1920. [Registered at the General Post Office as a Newspaper.] PRICE... 1s. 2d. BY FOREIGN POST...1s. 5½d.

A. G. Mumford, Ltd.,
CULVER STREET WORKS, COLCHESTER.
On Admiralty and War Office Lists.
ENGINES for Torpedo Boats, Yachts, Launches.
BOILER FEED PUMPS.
See Advertisement, pages 33 and 90.
PATENT WATER-TUBE BOILERS,
AUTOMATIC FEED REGULATORS,
And Auxiliary Machinery as supplied to the Admiralty. 8178

Rubber MANUFACTURERS
Hose Steam and Air Drill
GUTTA PERCHA & RUBBER, LIMITED,
Toronto - Canada. 8510

Bristol Pneumatic Tools. 8427
BOILER SCALERS. LTD.
See Advertisement last week, page 118.

Cranes.—Electric, Steam, HYDRAULIC and HAND.
of all types and sizes.
GEORGE RUSSELL & CO., LTD., Motherwell, near Glasgow. 8207

STEEL TANKS, PIPES, GASHOLDERS, &c.
Thos. Piggott & Co., Limited, BIRMINGHAM. 7411
See Advertisement last week, page 113.

Plenty and Son, LIMITED.
MARINE ENGINEERS, &c.
NEWBURY, ENGLAND. 9063

Tank Locomotives.
Specification and Workmanship equal to Main Line Locomotives.
R. & W. HAWTHORN, LESLIE & CO., LTD., ENGINEERS, NEWCASTLE-ON-TYNE. 8309

Cochran MULTITUBULAR AND CROSS-TUBE TYPES.
Boilers.
See page 17. 8205

Petter Oil Engines.
Manufactured by 3891
PETTERS LIMITED, Engineers, Yeovil.

"Spencer-Hopwood" Patent Sole Makers: **Boilers.**
W. H. SPENCER & CO., HITCHIN, HERTS.
See page 15. 8421

Invincible Gauge Glasses.
BUTTERWORTH BROS., Ltd.,
Newton Heath Glass Works,
Manchester. Od 9753

Electric Transporters.
S. H. HENWOOD & CO., LTD., REDDISH. 8143

Fuller, Horsey, Sons & Cassell,
SPECIALISTS
in the
SALE AND VALUATION
of
PLANT AND MACHINERY 1824
and
ENGINEERING WORKS
11, BILLITER SQUARE, E.C. 3.

Iron and Steel
Tubes and Fittings.
6220
The Scottish Tube Co., Ltd.,
HEAD OFFICE: 24, Robertson Street, Glasgow.
See Advertisement page 26, May 14.

Yarrow & Co., Ltd.,
SHIPBUILDERS AND ENGINEERS, GLASGOW.
SPEEDS UP TO 45 MILES AN HOUR.
PADDLE OR SCREW STEAMERS OF EXCEPTIONAL SHALLOW DRAUGHT.
Repairs on Pacific Coast
by YARROWS, LIMITED, Victoria, British Columbia, 7769
SHIPBUILDERS, SHIP REPAIRERS AND ENGINEERS.

Campbells & Hunter, Ltd.
Gear Cutting.
Worm Wheels cut up to 12 ft. diam.
Bevel and Mitre Wheels planed up to 3 ft. diam.
Spur Wheels cut up to 9 ft. diam.
DOLPHIN FOUNDRY, LEEDS. 4547

Yachts, Launches or Barges
Built complete with Steam, Oil or Petrol Motors; or Machinery supplied. Od 3551
VOSPER & CO., LTD., BROAD STREET, PORTSMOUTH.

FOR
Drop Forgings
write
GARTSHERRIE ENGINEERING & FORGE CO., 50, Wellington Street, Glasgow. 7806

OIL FUEL APPLIANCES.
Systems
PRESSURE, AIR, STEAM.
For Boilers of all types.
KERMODES LIMITED,
35, The Temple, Dale Street, Liverpool; and
109, Fenchurch St., London.
Naval Outfits a Speciality.
4078

Locomotives Tank Engines
designed and constructed by
MANNING, WARDLE AND COMPANY, LIMITED, Boyne Engine Works, Leeds Od 2487
See their Illus. Advertisement, page 120, last week.

RAILWAY AND TRAMWAY ROLLING STOCK.
Hurst, Nelson & Co., Ltd.
THE GLASGOW ROLLING STOCK AND PLANT WORKS, MOTHERWELL. Od 2333

The Cambridge and Paul Instrument Co. Ltd.,
Manufacturers of Mechanical and Electrical Instruments of Precision.
WORKS: Cambridge and New Southgate, London, N. 11. 8196

Henry Butcher & Co.,
VALUERS AND AUCTIONEERS
to the
ENGINEERING AND ALLIED TRADES.
ALSO FOR
PLANT AND MACHINERY. 8134
63 and 64, CHANCERY LANE, W.C. 2.

Electric Lifts
(UP TO 35 TONS.) 8143
S. H. HENWOOD & CO., LTD., REDDISH.

"Aptol"
Lubricating Oils
ARE ALL
"Germ Process" Oils
GIVING
Greatest Economy.
Henry Wells Oil Co.,
11, HAYMARKET, S.W. 1. 8256

FOR
Railway Wagon Couplings
and GENERAL SMITHY WORK,
write
WELDLESS CHAINS, LTD., Cwmbridge. 8184

John Bellamy, Limited,
MILLWALL, LONDON, E. 1216
GENERAL CONSTRUCTIONAL ENGINEERS,
Boilers, Tanks, & Mooring Buoys
STILLS, PETROL TANKS, AIR RECEIVERS, STEEL CHIMNEYS, RIVETED STEAM AND VENTILATING PIPES, HOPPERS, SPECIAL WORK, REPAIRS OF ALL KINDS.

Tubes and Fittings.

Stewarts and Lloyds, Ltd.,
Glasgow and Birmingham.
See Advertisement page 76. 6187

CO_2 Plants (CARBON DI-OXIDE)
for Chemical Wks., Mineral Water Mfrs., Breweries, and all other purposes.—SPARKLETS AND GENERAL Mfg. Co., Ltd., Edmonton, London, N. 18. 7896

Die Finished Castings ensure rapid production and reduce prime cost by eliminating machining operations. Write for illustrations to SPARKLETS AND GENERAL Mfg. Co., Ltd., Edmonton, London, N. 18. 7896

Machine and Engineering
WORK UNDERTAKEN
for G 698
MANUFACTURERS, PATENTEES, etc.
Apply:
WHITEHEAD TORPEDO WORKS, (WEYMOUTH), LTD., Weymouth.

Cement.—Maxted & Knott, LTD., Consulting Cement Engineers, ADVISE GENERALLY on proposed Cement Schemes FOR ENGLAND AND ABROAD. ADVICE ONLY. Highest references. Established 1860.
Address, BURNETT AVENUE, HULL.
Cablegrams: "Energy, Hull." 7901

CHANTIERS & ATELIERS
Augustin-Normand
67, rue de Perrey—LE HAVRE (France).
3880
Destroyers, Torpedo Boats, Yachts and Fast Boats, Submarine and Submersible Boats.
NORMAND'S Patent Water-tube Boilers, Coal or Oil Heating. Diesel Oil Engines.

ON ADMIRALTY LIST.
John Kirkaldy, Ltd.,
London Office: 101, LEADENHALL ST., E.C. 3.
Works: BURNT MILL, near HARLOW, ESSEX.
Makers of
Evaporating and Distilling Plants.
Refrigerating and Ice Making Machinery.
Feed Water Heaters.
Evaporators.
Fresh Water Distillers.
Main Feed Pumps.
Combined Circulating and Air Pumps.
Auxiliary Surface Condensers.
&c. &c. 7726

Electric Cranes.
8143
S. H. HENWOOD & CO., LTD., REDDISH.

The Glasgow Railway Engineering Company,
GOVAN, GLASGOW. LTD.,
London Office—13, Victoria Street, S.W.
MANUFACTURERS OF
RAILWAY CARRIAGE, WAGON & TRAMWAY WHEELS & AXLES,
CARRIAGE & WAGON IRONWORK, also CAST-STEEL AXLE BOXES. 8237

Measuring Machines
FROM
Stock.
THE
Newall Engineering Co.
(Proprietors, Peter Hooker, Ltd.),
LONDON, N. 17. 7826

Royles Limited,
ENGINEERS, IRLAM, MANCHESTER.
FEED WATER HEATERS, CALORIFIERS, EVAPORATORS, CONDENSERS, AIR HEATERS, STEAM AND GAS KETTLES, Row's Patents
Merrill's Patent TWIN STRAINERS for Pump Suctions.
SYPHONIA STEAM TRAPS, REDUCING VALVES
High-class GUNMETAL STEAM FITTINGS
WATER SOFTENING and FILTERING. 8723

Yarrow Patent Water-tube Boilers. 7788
Messrs. YARROW & CO., UNDERTAKE the PRESSING and MACHINING of the various parts of Yarrow Boilers, such as the Steam Drums, Water Pockets, and Superheaters for British and Foreign Firms not having the necessary facilities.
YARROW & CO., LTD., SCOTSTOUN, GLASGOW.

Matthew Paul & Co., Ltd.
LEVENFORD WORKS, **Dumbarton,** 7680
See Full Page Advt., page 91, April 30.

Forgings.
Walter Somers & Co., Ltd., HALESOWEN. 7116

Head, Wrightson & Co.,
LIMITED.
See Advertisement page 90. 9402

Taylor & Challen Presses. 8195
TAYLOR & CHALLEN, LD., Engineers, BIRMINGHAM.
See Full Page Advertisement, April 30.

Railway Switches and Crossings.
T. SUMMERSON & SONS, LIMITED, DARLINGTON. 7903

AERIAL ROPEWAYS, CABLEWAYS, CRANES.
Steel Castings. 8181
See displayed advertisement every fourth week.
JOHN M. HENDERSON & CO., ABERDEEN.

E. J. Davis, M.I.Mech.E.,
Gas Engines Inspected, Tested and Reported Upon. Over 25 years' experience. Tel.: 736 and 737 Stratford. Wire: "Rapidising, London."—Great Eastern Road, Stratford, E. 15. 1794

Machine and Engineering
WORK of all description undertaken for Manufacturers, Patentees, &c. Also repairs and renewals. Best work moderate charges.—ROSSER & RUSSELL, LTD., Queen's Wharf, Hammersmith.
NEW PATENT AUT.—ROSSER & RUSSELL, Ltd., are prepared to undertake the manufacture of articles at present made abroad, and will be pleased to hear from firms desiring such work executed. 9311

Locomotive Traversers (ELECTRIC). 8143
S. H. HENWOOD & CO., LTD., REDDISH.

Dredging Plant
OF ALL DESCRIPTIONS.
FLOATING CRANES. COAL BUNKERING VESSELS.
Werf Conrad, HAARLEM, HOLLAND,
Agents: MARINE WORKS, LTD., FRIARS HOUSE, 39-41, NEW BROAD ST., LONDON, E.C. 2.
See half-page Advert. last week and next week. 8490

Centrifugals.
Pott, Cassels & Williamson,
MOTHERWELL, SCOTLAND. 7941
See half-page Advertisement page 91, May 14.

The Manchester Steam Users' ASSOCIATION,

For the prevention of Steam Boiler Explosions and for the attainment of Economy in the Application of Steam. 9, MOUNT STREET, MANCHESTER.
Chief Engineer: C. E. STROMEYER, M.I.C.E.
Founded 1854 by SIR WILLIAM FAIRBAIRN.
Certificates of Safety issued under the Factory and Workshops Act, 1901. Compensation for Damages and Liabilities paid in case of Explosions. Engines and Boilers inspected during construction. 8443

The National Foremen's ASSOCIATION OF THE ENGINEERING AND ALLIED TRADES.

(Registered under the Trade Union Act.)

An Association specially formed to look after the interests of Foremen on their Supervisory Capacity. F 601

All communications to— H. W. RHID, General Secretary. Head Offices— 91, High Holborn London, W.C. 1.

University of London.

The COURSE of FOUR ADVANCED LECTURES on "High-frequency Alternators for Radio Telegraphy," by Monsieur MARIUS LATOUR, of Paris, has now been arranged definitely to take place at the Institution of Civil Engineers, Great George Street, S.W. 1, at 8.30 p.m., on MAY 26th, 27th, 28th and 31st.
Admission is free to the Lectures, which are addressed to Advanced Students of the University and others interested in the subject. Syllabus obtainable on application.
P. J. HARTOG, Academic Registrar. G 581

Inst. C.E. Exams.—Over 300

successes by Correspondence Coaching. Several prizes. Sec. "U" now prepared. (Designs, Specifications and Quantities). A few vacancies open.—Address, 7434, Offices of ENGINEERING.

Correspondence Courses for

B.Sc., Inst. C.E., I. Mech. E., all ENGINEERING EXAMS. Special Courses and Single Subjects. Personal tuition.—For full particulars apply to MR. TREVOR W. PHILLIPS, B.Sc. (Hons.), Assoc.M.Inst.C.E., M.R.S.I., etc., 5-10, Trafford Chambers, 55, South John Street, Liverpool. 8428

Inst. C.E., I. Mech. E., B.Sc., and all Engineering Examinations.—Mr. G. F. KNOWLES, B.Sc., Assoc. M. Inst. C.E., F.S.I., M.R.San.I., PREPARES CANDIDATES personally or by correspondence. Hundreds of successes. Courses may commence at any time.—39, Victoria St., Westminster, S.W. 8039

London C.E., Honours Grad.,

PREPARES MEN by PERSONAL TUITION for A.M.I.C.E., Inst.Mech.E., and other exams. NO FAILURES during 30 years' experience.—For terms, address F 913, Offices of ENGINEERING.

Engineering Special Classes.

Marine & Aero-Engines, Alternating Currents, Wireless Course, Ferro-Concrete, Refrigeration, Pract. Maths. and Calculus.—PENNINGTONS, University Tutors, 264, Oxford Rd., Manchester.

TENDERS.

LONDON COUNTY COUNCIL.

The Council invites

Tenders for the Reconstruction

and WIDENING of PRIEST'S BRIDGE carrying Upper Richmond Road over Beverley Brook.
Persons desiring to Tender may obtain the specifications, bills of quantities, form of Tender, drawings, etc., on application to the CHIEF ENGINEER at the County Hall, Spring Gardens, S.W. 1, upon payment to the Cashier of the Council of the sum of £3. This amount will be returnable only if the Tenderer shall have sent in a bona fide Tender and shall not have withdrawn the same. Full particulars of the work may be obtained on personal application, and the drawings, specification and other contract documents may be inspected, at the County Hall before the payment of the fee. No Tender received after Four p.m., on Monday, 14th June, 1920, will be considered.
The Council does not bind itself to accept the lowest or any Tender.
JAMES BIRD, Clerk of the London County Council. G 676

LONDON COUNTY COUNCIL.

The Council invites

Tenders for Two Sewer CONTRACTS.

CONTRACT No. 1 for the Construction of about 5402 ft. 1 in. of BRICK SEWER 8 ft. internal diameter in tunnel and about 7331 ft. 1 in. of BRICK SEWER 9 ft. internal diameter in tunnel from Kelvin Road, Highbury, to Bethnal Green, Road, with special works in Junctions and Overflow Chambers, etc.
CONTRACT No 2 for the Construction of about 7702 ft. 1 in. CAST IRON SEWER 11 ft. 4 in. internal diameter in tunnel, including two short lengths in compressed air and about 302 ft. 1 in. of BRICK SEWER 11 ft. 4 in. internal diameter in tunnel and about 215 ft. 1 in. of BRICK SEWER 11 ft. 4 in. internal diameter in open cut from Bethnal Green Road to the River Thames with special works in Junctions and Overflow Chambers and Outlet to River.
Persons desiring to tender may obtain the Specification, Bills of Quantities, Form of Tender, etc., on application to the CHIEF ENGINEER, at the County Hall, Spring Gardens, S.W. 1, upon payment to the Cashier of the Council of the sum of £5 for each contract. This amount will be returnable only if the Tenderer shall have sent in a *bona fide* Tender, and shall not have withdrawn the same. Full particulars of the work may be obtained on personal application, and the drawings, specification and other contract documents may be inspected at the County Hall before the payment of the fee.
No Tender received after Four p.m., on Monday, 14th June, 1920, will be considered.
The Council does not bind itself to accept the lowest or any Tender. G 677
JAMES BIRD, Clerk of the London County Council.

CITY OF BRADFORD.

ESHOLT SEWAGE DISPOSAL WORKS.

CONTRACT No. 32.

STEEL FRAMEWORK OF BUILDINGS, ETC.

The Corporation are prepared to receive

Tenders for the Supply,

DELIVERY and ERECTION of the STEEL FRAMEWORK of a Building with a flat roof, 50 ft. long by 44 ft. wide by 40 ft. high, together with STEEL ROOF TRUSSES for a Building 66 ft. 6 in. long by 34 ft. wide.
Drawings may be seen and copies of Specification, Quantities and Form of Tender may be obtained on and after Wednesday the 26th May, 1920, at the office of Mr. JOSEPH GARFIELD, M. Inst. C.E., Sewageworks Engineer, Esholt Hall, Shipley (station, Apperley Bridge, Midland Railway).
Tenders, endorsed "Esholt Sewage Disposal Works—Contract No. 32," must be delivered at the office of the undersigned not later than Nine a.m., on Wednesday, the 2nd June, 1920.
The Contract will be subject to the Fair Contracts Clauses of the Corporation, which may be seen at the Sewageworks Engineer's Office, and which the accepted Contractor will be required to sign.
The Corporation do not bind themselves to accept the lowest or any Tender.
NORMAN L. FLEMING, Town Clerk.
Town Hall, Bradford.
May, 1920. G 569

G. R.

MINISTRY OF MUNITIONS.

BY DIRECTION OF THE DISPOSAL BOARD (PLANT AND MACHINERY SECTION).

FOR SALE BY TENDER.

KITE BALLOON MACHINERY, At HOUTON BAY, ORKNEY ISLANDS.

Tenders are Invited for the

following:—
One 26 HP. MOTOR, 440 volts, D.C. Makers: Messrs. Scott. Complete with Starter and Switch.
Two PUMPS (Lee Howl Mechanical).
One PUMP, Worthington Vertical Triplex 5½ in. by 8 in.
One GAS PLANT, "B" type.
Consisting of cylindrical Generator, Coke scrubber, two Soda mixing tanks, mechanically operated stirring gear in cylindrical hopper and Generator. Wet feed Silicol, admission gear, overhead water tank, hand crane. Water cooling tower, complete with circulating pump and motor, and all pipes in connection to suit.
One 44 HP. DORMAN PETROL ENGINE, 130 mm. by 140 mm. stroke.
Two Compressors, Murray Workman, three stage type to compress 2500 cubic feet of free hydrogen per hour to a pressure of 1800 lbs. per square inch, for charging hydrogen cylinders.
Full particulars and Tender Forms may be obtained on application to the CONTROLLER, Plant and Machinery Section, Charing Cross Embankment Buildings, London, W.C. 2.
TENDERS CLOSE on JUNE 1ST, 1920.
NOTE.—For particulars of other Government Property for Sale, see *Surplus*, price 3d. at all Bookstalls; or by quarterly subscription of 2s. post free in the United Kingdom, payable in advance to the Director of Publicity, Ministry of Munitions, Whitehall Place, London, S.W. 1. G 426

G. R.

MINISTRY OF MUNITIONS.

BY DIRECTION OF THE DISPOSAL BOARD. (PLANT AND MACHINERY SECTION).

For Sale by Public Tender,

TOLUOL PLANTS,
At MANCHESTER CORPORATION GASWORKS, Bradford Road, Manchester.
Six Tower Scrubbers, Carburettors, Steel frame Benzol House, Crude Still, Primary and Secondary Rectification Stills, Oil and Water Coolers, Pumps, Two Boilers and One Pump, Chimney and Steel frame Boiler House, etc.
At NEEPSEND WORKS of the SHEFFIELD GAS CO.
Oil Tanks, Coils for Heat Exchanger, Oil Still, Pumps, Coolers, Condensers, Benzol Still, Benzol Washers, Acid and Soda Tanks, Rectification Still, Petrol Pumps, and Steel Frame Benzol and Exhauster Houses.
At GRIMESTHORPE WORKS of the SHEFFIELD GAS CO.
Heat Exchanger, Pre Heater, Oil Still, Receiver, Cooler, Condenser, Benzol Condensers, Pumps, and Steel frame Benzol House.
At GRANTON GASWORKS, EDINBURGH, and LEITH COMMISSIONERS.
Heat Exchangers, Oil Pumps, Coolers, Benzol Condensers, Crystallising Tanks, Pumps, Storage Tanks, etc.
At PROVAN GASWORKS, GLASGOW.
Heat Exchangers, Oil Pumps, Cooler, Pre Heater-Still, Benzol Still and Condenser, Condensers and Chimneys, Naphthalene Separators, Rectification Column, Benzol, Toluol, and Solvent Condensers, Pumps, Steel frame Plant House, Heavy Oil Still, Coolers, Spares, etc.
Detailed particulars, permit to View and Tender Forms, can be obtained on application to CONTROLLER, D.B.I.B., Plant and Machinery Section, Charing Cross Huts, Embankment, W.C. 2.
Tenders to be returned not later than 10 a.m. on the 29th May, 1920.
NOTE.—For particulars of other Government Property for Sale, see *Surplus*, price 3d. at all bookstalls; or by quarterly subscription of 2s. post free in the United Kingdom, payable in advance to the Director of Publicity, Ministry of Munitions, Whitehall Place, London, S.W. 1. G 299

TO MILLWRIGHTS.

Tenders Invited to Renew

OVERSHOT WHEEL 11 ft. 6 in. diameter, and Water gates, capacity, width 7ft. 6in. depth 8ft. Frame over all 11 ft. at Ifield Mill, Crawley.—BECKHUSON, Warnford Court, London. G 675

OLD RAILS FOR SALE.

THE CORK, BANDON & SOUTH COAST RAILWAY COMPANY are prepared to receive

Tenders for the Purchase of

about 500 Second-hand STEEL FLANGE RAILS, originally 65 lbs. per yard, in 30 ft. and 99 ft. 10 in. lengths, with Fishplates to match; and of 325 Second-hand STEEL FLANGE RAILS, originally 62½ lbs. per yard, with plates to match.
Tenders, marked "Tender for Old Rails," to be sent in on or before 31st May, 1920, to the SECRETARY, from whom full particulars and Form of Tender can be obtained.
R. H. LESLIE, Secretary, Albert Quay, Cork.
13th May, 1920. G 556

MIDLAND GREAT WESTERN RAILWAY OF IRELAND COMPANY.

ENGINES AND MACHINERY FOR SALE.

The Directors of the above Company are prepared to receive

Tenders for the Sale of

ENGINES and MACHINERY in old Canal Steamer, which can be seen at Royal Canal Dockyard, Phibsborough, Dublin. The engines and machinery to be removed by purchaser, the Company providing any necessary dockage free.
Full particulars on application to CHIEF ENGINEER, Broadstone Station, Dublin.
Tenders to be forwarded so as to reach the undersigned not later than Monday, 7th June, 1920.
The Directors do not bind themselves to accept the highest or any Tender.
PERCY A. HAY, Secretary.
Broadstone Terminus, Dublin.
19th May, 1920. G 695

LONDON COUNTY COUNCIL.

The Council invites

Tenders for the Manufacture

and ERECTION at Abbey Mills Pumping Station, Stratford, E. 15, of Two 30 ft. by 8 ft. LANCASHIRE BOILERS, together with fittings, dampers, etc.; working pressure 150 lbs. a square inch.
Persons desiring to tender may obtain the Specifications, Bills of Quantities, Form of Tender, etc., on application to the CHIEF ENGINEER, at the County Hall, Spring Gardens, S.W., upon payment to the Cashier of the Council of the sum of £3. This amount will be returnable only if the Tenderer shall have sent in a bona fide Tender, and shall not have withdrawn the same. Full particulars of the work may be obtained on personal application, and the Drawings, Specification and other Contract documents may be inspected at the County Hall before the payment of the fee.
Tenders must be upon the official forms. No Tender received after Four p.m., on Monday, 21st June, 1920, will be considered. The Council does not bind itself to accept the lowest or any Tender.
JAMES BIRD, Clerk of the London County Council. G 613

APPOINTMENTS OPEN.

THE GENERAL ENGINEERING COLLEGE, 2, Penywern Road, S.W. 5.

Required, Competent

INSTRUCTOR in the Drawing Office. Subjects:—Geometrical, Solid and Elementary Mechanical Drawing.
Applications to be made to the Principal, J. H. REEVES, M.A. G 555

CITY OF BIRMINGHAM EDUCATION COMMITTEE.

HANDSWORTH JUNIOR DAY TECHNICAL SCHOOL.

An Assistant Master for

Engineering Drawing is required for the term commencing in September next. Candidates must have had Works experience. Salary will be paid on the Secondary School scale. Forms of application and copy of present Scale of Salaries may be obtained from the undersigned. At present a War Bonus of £74 or £78 per annum, according to salary, is paid.
Applications must be sent in not later than 31st May.
P. D. INNES, Chief Education Officer.
Education Office, Council House, Margaret Street. G 522

SUNDERLAND EDUCATION COMMITTEE.

THE TECHNICAL COLLEGE.

DEPARTMENT OF MATHEMATICS AND MECHANICS.

The Committee invite

Applications for the Position

of LECTURER in the Department of Mathematics and Mechanics. Applicants must possess a University Degree, or its equivalent, training in Mathematics and Experimental Mechanics, and teaching experience in a Technical Institution.
Particulars of appointment, with Scale of Salaries and Regulations Governing Appointments, may be obtained from the Principal of the Technical College, Sunderland.
Applicants must apply by letter, with reference or copies of recent testimonials, to the undersigned on or before Monday, 31st May, 1920.
HERBERT REID, Chief Education Officer.
Education Department, 15, John Street, Sunderland. G 301

BATTERSEA POLYTECHNIC, LONDON, S.W. 11.

The Governing Body invite

Applications for Two Posts

as ASSISTANT LECTURER and DEMONSTRATOR in Electrical Engineering. Commencing salary, according to qualifications and experience, up to £315, rising to £440 in accordance with London County Council Scale.
Particulars can be had upon application to the Secretary. G 832

RESEARCH ASSOCIATION OF BRITISH RUBBER AND TYRE MANUFACTURERS.

This Association is now considering the appointment of Research Assistants, and invites

Applications from Chemists

and PHYSICISTS possessing experience in carrying out original scientific investigations, and from men with scientific training combined with some experience in mechanical testing, preferably in connection with Rubber.
Address applications, with full particulars and salary required, to:—
THE DIRECTOR OF RESEARCH, W. B. PEAT & Co., 11, Ironmonger Lane, E.C. 2. G 871

MANCHESTER MUNICIPAL COLLEGE OF TECHNOLOGY.

APPOINTMENT OF A DIRECTOR OF STUDIES.

The Governing Body invites

Applications for Appointment

as DIRECTOR OF STUDIES in the College of Technology, at a salary of £600 a year.
The conditions of appointment and forms of application may be obtained from the REGISTRAR, College of Technology, Manchester. The last day for the receipt of applications (which should be addressed to the REGISTRAR) is Tuesday, 15th June.
Canvassing Members of the Governing Body, either directly or indirectly, will disqualify a candidate. G 590

TECHNICAL INSTITUTE, WALTHAMSTOW.

Principal—JAMES G. B. EDWARDS, A.M.I.M.E.

The Governors invite

Applications for the Following POSTS in the Day Department of the Technical Institute:—

(1) LECTURER in ENGINEERING.
Commencing Salary—£350 per annum.
(2) TEACHER of PRACTICAL MATHEMATICS.
Commencing Salary—£240 per annum.
(3) INSTRUCTOR in WOOD WORKSHOP PRACTICE.
Commencing Salary—£250–£275.

Applications for this post should be sent in immediately. A knowledge of pattern making will be a recommendation.
For (1) and (2), Candidates should possess a University degree or its equivalent, and for (1) and (3), should have had practical Workshop experience.
Application Forms which must be returned for (1) and (2) not later than May 29th, may be obtained from R. DEMPSEY, Clerk to the Governors, 1, Selbourne Road, Walthamstow. G 409

SUNDERLAND EDUCATION COMMITTEE.

THE TECHNICAL COLLEGE.

SUPERINTENDENT OF TRAINING FOR CONTINUATION AND TECHNICAL SCHOOL TEACHERS.

Applications are Invited for

the above POSITION, which is being established for the purpose of training intending teachers of Continuation and Technical Schools, who have had some experience in engineering works and shipyards. The Technical College provides full-time day advanced courses in engineering and science of a University type, and part-time courses in naval architecture, engineering, building, etc.
The Superintendent of Training will be required to organize (i) courses of training for students who have completed both their full-time day advanced courses in engineering, etc., and their apprenticeship; (ii) short courses for part-time technical teachers engaged in engineering works and shipyards; (iii) short courses for technical teachers already in the employ of the Committee; and (iv) such other duties as may be detailed by the Committee.
Candidates must possess a University Degree, or its equivalent, and it is desirable that he should have some knowledge of Technical School work, and also some experience in welfare work for boys.
Salary according to scale, £450–£25–£550.
Applications, accompanied by three recent testimonials and references, must reach the undersigned by June 5th, 1920.
HERBERT REID, Chief Education Officer.
Education Department, 15, John Street, Sunderland. G 300

Assistant Superintendent

REQUIRED for Iron Foundry of large Engineering Firm. Good practical experience essential.—Address, stating age, experience and salary required, G 341, Offices of ENGINEERING.

Boiler Inspector.—Wanted by

the MANCHESTER STEAM USERS' ASSOCIATION, a practical ENGINEER, age 25 to 35, conversant with the construction of Boilers and Steam Plants, to fill the position of Inspector; the duties will require him to examine boilers internally and also to go up the flues; he must be capable of taking boiler dimensions, making sketches of boilers, and drawing up reports.—Apply by letter, stating age, experience and previous engagements, &c., to the SECRETARY, 9, Mount Street, Manchester. G 622

Wanted a Man who is

thoroughly conversant with all temperature recording instruments, electrical and mechanical in use in Iron and Steel works. Apply, giving full particulars, to G 548, Offices of ENGINEERING.

Foundry Metallurgist Wanted,

ferrous and non-ferrous, for large Engineering works near Manchester. Graduate preferred.—Address, stating age, education, experience, and salary, G 559, Offices of ENGINEERING.

COLLISION DYNAMICS.

By G. GREENHILL.

(*Continued from page* 605.)

14. Dynamical experiments are to be discouraged on the small scale of a lecture table, as friction has an inordinate influence in masking the result of a research measurement; they should be used for mere illustration. And the true Laws of Motion were not discovered till after a study of the motion of the heavenly bodies, subject to no apparent retardation of frictional effect.

Thus, Atwood's machine should be mentioned only as of historical interest, but not capable of giving the exact result of Galileo's pendulum. The motion of the weights, up and down, casts a doubt in many minds, thinking unconsciously in the Doctrine of Relativity. And Bouasse decries the ordinary cathetometer for a similar reason, as never seen except on the lecture table.

Galileo's attention was directed to the swinging lamp in the Cathedral of Pisa, as beating out equal intervals of time, and so it suggested an instrument better adapted for dynamical teaching than the clepsydra of his lecture room. The law connecting the beat t and length l was soon established experimentally, and expressed in the formula $t = \sqrt{\frac{l}{L}}$, where L is the length beating the second.

This is the more logical form of the formula, and it is the one employed in the Principia, and not the usual $t = \pi\sqrt{\frac{l}{g}}$, because g is not measured directly with any accuracy, say in Atwood's machine, equal to that obtained from the pendulum experiment for determining L, and then g is derived by calculation from the formula $g = \pi^2 L$.

Although an appeal has been decried to the experiment of the lecture room, a simple apparatus may find place on the wall, to show off the Law of the Pendulum, consisting of a rod O A pivoted at O, and carrying a number of plummets suspended by thread. (Fig. 5.)

The rod can be held up by a cord A B, and the points of suspension, C_1, C_1, C_1, C_1, C_5, made equidistant, say, 10 in (25 cm) apart, and the length of thread adjusted to make the plummets beat 1, 2, 3, 4, 5, quarter seconds; so that taking L the length beating the second at 40 in (1 metre) in round numbers, the thread lengths are 2·5, 10, 22·5, 40, 62·5 in (6·25, 25, 56·25, 100, 156·25 cm).

A slight jerk of the cord A B will set all the plummets wagging from rest; and after 15 seconds, their Annus Magnus or Saros, of 60 quarter-second beats, the G.C.M. of the beats, the plummets should all be seen caught in the same phase again.

The lengths may be laid off geometrically as in the figure, by taking O C = 40, C P = 40, inches, and dividing C P into intervals of 10 in by the points Q_1, Q_2, Q_3, P, Q_5, . . . Then O Q_1 cuts the thread through C_1 in P_1; and so on.

The plummets are seen to lie on a parabola; and as we have made O C = C P, the focus is at a distance from O equal to ¼ C P = C_2P_2 = 10 in; and O S remains constant for any inclination of the rod O C.

The plummets represent also the position at equal intervals of time of a ball projected from O in the direction O C, with velocity which would carry it up to the directrix, at a height O X = 10 in (25 cm) above O, or be acquired in falling from the level of X; and C_2 P is the tangent at P; and so for any other point.

The successful application of the pendulum to a clock was not made in Galileo's lifetime, but is due more to Huygens, Horologium oscillatorium, 1673.

But a Galileo pendulum, a thread with a plumb bob, is the most accurate of all apparatus in dynamical measurement of time.

A ball rolling down a sloping desk, or two balls rolling side by side, will serve for showing the dilution of gravity on the inclined plane, such as a road; and then with a Galileo pendulum to beat the time, it is realised that the balls, starting from rest, roll down four-fold distance in two beats, nine-fold in three beats, and so on.

Mach's stimulating lectures on the "Science of Mechanics" should be ever in the mind of the instructor, to show how to vary these simple experiments, such as letting two different balls roll down, when they move side by side, whatever the weight, size or material; also in the plumb bob changing the material is immaterial; as also of the walls of the room, all matter and space being transparent to gravity.

15. The pendulum will serve to measure the size of the earth in the lecture room, knowing the distance of the moon and her period, looking them out from the Nautical Almanack. Taking the mean parallax at 57′, and the lunation as 27 days 6 hours, the quadrant of the earth works out to about ten million times the length of the pendulum beating

Fig. 5.

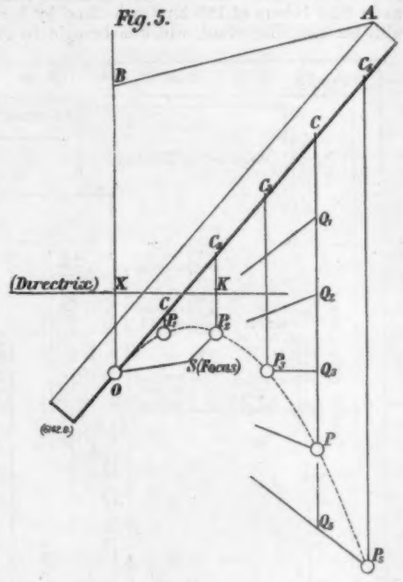
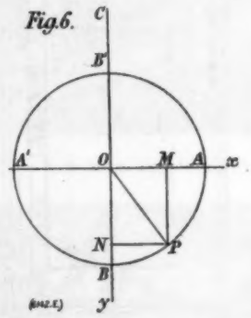


Fig. 6.



seconds, that is 10,000,000 metres, as settled in the metric system. with the length of the pendulum taken as 1 metre, nearly.

The range r of the moon, in terms of Q, the quadrant of a meridian of the earth, is given by

$$r = \frac{2Q}{\pi}\ \text{cosec}\ 57' = \frac{120\,Q}{\pi}, \text{ with cosec } 57' = 60;$$

and if T denotes in seconds the period of the lunation, 27½ days, M in minutes, H in hours, H = 654, the acceleration of gravity at the moon

$$\frac{4\pi^2 r}{T^2} = \frac{g}{60^2} = \frac{\pi^2 L}{60^2}, \quad L = 4r\left(\frac{60}{T}\right)^2 = \frac{4r}{M^2},$$

$$\frac{Q}{L} = M^2\,\frac{Q}{4r} = \frac{\pi M^2}{480} = 7{\cdot}5\,\pi H^2$$

7·5	= al	0.8751
π	= al	0·4971
H = 654, H^2	= al	5.6312
$\frac{Q}{L}$	= al	7.0034
and with L = 0·994	= al	1.9974
Q	= al	$7.0008 = 10^7 \times 1.002$,

say ten million metres. and 20 km over.

16. The Law of the Spring has been taken for granted at the outset in the investigation of elastic buffers in collision, and here a pendulum length is an appropriate measure.

Suspend a weight in an ordinary spring balance, and set it vibrating vertically: the weight is found to beat time with a pendulum length equal to the deflection on the scale, that is supposing the graduation is uniform, according to the Law of the Spring.

Or superpose a carriage body on the springs over the wheels, and note the distance it sinks down to rest, the vertical set. The vertical oscillation of the body will beat time with a pendulum length equal to this permanent average vertical set.

We call this periodic motion a "simple vibration;" no need to add the name "harmonic," reserving harmonic for the overtone vibrations of a musical note, as in the terms of a Fourier series.

In the experimental comparison of these simple vibrations, start with the theory of the motion of a body on springs, as no approximation is required in the treatment if the Law of the Spring is supposed to hold to any extent.

Take a simple Salter balance, with uniform graduations, and suspend a weight W lb, to produce a vertical set CO = l on the scale. The weight W is drawn down to B a distance O B = a, and let go; it proceeds to oscillate up to B′ and back again, to an equal distance above and below O. (Fig. 6).

At B the tension of the spring, upward on W, is increased from W to $W\frac{OB}{CO} = W\left(1+\frac{a}{l}\right)$, and the upward unbalanced force giving the motion to W is $W\frac{a}{l}$ reduced to $W\frac{y}{l}$ at N, a depth of y below O. The average force between B and N is $W\frac{\frac{1}{2}(a+y)}{l}$, and acting through B N = $a - y$ does work $W\frac{\frac{1}{2}(a^2-y^2)}{l}$ ft-lb to be equated to $W\frac{v^2}{2g}$, the K E acquired by the body; then dividing out W, and putting $g = ln^2$,

$$v^2 = n^2(a^2 - y^2) = n^2 \cdot N\,P^2 = n^2 \cdot B\,N \cdot N\,B',$$

so that v is n times N P, or n times the geometric mean (G.M.) of the distances of N from B and B′.

Then in the triangle of velocity O N P, the point P of the circle on diameter B B′, at the same level as N, has the velocity n, O P = $n\,a$ at right angles to O P, the velocity of N being n, N P at right angles to N P; so that P circulates round the circle B P B′ with constant velocity, $n\,a$, while N follows it at the same level on the diameter B B′, as in the motion of a vertical donkey engine pump, with no connecting rod, but the crank pin working in a horizontal slot, P being the crank pin of the flywheel axle, and N on the head of the piston rod or plunger.

Reckoning the time t from the start at B, the arc B P = $n\,t\,a$, the angle B O P = $n\,t$, radians, and it is called the "phase angle,"

$$y = a\cos nt, \qquad v = na\sin nt,$$

v with the minus sign if positive in the direction of the increase of y.

In another crank or eccentric in a different phase on the same shaft through O, the phase angle would be altered by a constant phase ϵ to $nt + \epsilon$, and the ϵ is called the "lead," or if negative the "lag."

The time of a stroke from B to B′ is π/n, and in a revolution of the crank is $2\pi/n$, with $n = \sqrt{(g/l)}$.

In the projection at M of the motion of P on the horizontal line Ox,

$$x = OM = a\sin nt, \qquad u = na\cos nt,$$

giving u the velocity of M, which moves like the piston of a horizontal engine or locomotive, ignoring any fluctuation due to obliquity of connecting rod.

The acceleration of P is n^2 . P O to O, and its components, n^2. M O and n^2. N O, give the acceleration of M and N to O.

The horizontal vibration of M between A and A′ is imitated very closely, and quite near enough for our purpose, by the vibration of the bob of a pendulum of length l, provided l is large compared with the extent of stroke A A′; but here the vibration in the pendulum arises from the curvature of the circular arc at its lowest point O, such that the force on the bob W at an arcual distance x from O is W sin (x/l) back to O, and sin (x/l) can be replaced by x/l, if small enough, as in our experiment.

The phase angle measures the time, and so its subdivision. For example, the mid-beat of the piston stroke or pendulum is described in one-third of the time of the stroke or beat.

The tension of the spring would change to a

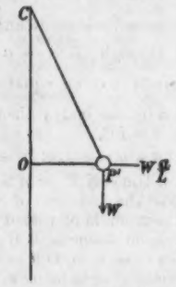
thrust if a was large or l small enough for C to come below B′. A weight in the scale pan of the balance would lose contact above C, unless tied down; and small objects would move about, as if on the deck of a steamer, or destroyer, in violent vibration. In the equivalent steam engine a knock would be heard.

Yarrow's vibrometer, Schlick's pallograph, and Bragg's listening apparatus, described in ENGINEERING, June 13, 1919, depend on an application of the same theory, for investigating when chattering begins at a contact. The method was known to the ancients, and is described by Herodotus, book IV, 200.

17. But just as the obliquity effect of the connecting rod disturbs the exactness of the simple vibration of M, in a similar way the divergence of $\sin(x/l)$ and x/l causes the "circular correction" to become perceptible, as in a clock pendulum; and with unlimited extent of oscillation the complete treatment of the simple pendulum requires the resources of the Elliptic Function, and this would take us too far at present, although demanded by a careful thinker, unconvinced by the usual jaunty approximation of the elementary text-book.

But arguing from the analogy of the simple vibration of M, making an excursion A A′ about the

Fig. 7.



lowest point O, slight compared with the length l, the beat of a pendulum of length l is taken as

$$\frac{\tau}{n} = \pi\sqrt{\frac{l}{g}},$$

and the double beat or period

$$2\pi\sqrt{\frac{l}{g}},$$

and this is the period if we are allowed to give a conical motion to our pendulum, where the bob P describes a horizontal circle A P A′ on the diameter A A′, seen rebatted in a vertical plane in the figure, but viewed horizontally edgeways in A O A.′ The analogy is then exact with simple vibration, and no approximation or Elliptic Function is required, provided l is taken as the vertical depth of the circle A A′ below C the point of suspension.

Because in the triangle of force C P O of Fig. 7 and in the circular motion of P, with velocity $n\,a$ at a radius a, the centrifugal force (C.F.)

$$W\frac{v^2}{g\,a} = Wn^2\frac{a}{g} = W\frac{a}{l},$$

$$\frac{\text{C.F}}{\text{gravity}} = \frac{W\frac{a}{l}}{W} = \frac{a}{l} = \frac{\text{O P}}{\text{O C}}.$$

Hence in all calculations involving centrifugal force in rotating bodies, the height l of the equivalent conical pendulum is a convenient geometrical length to use for simplification in the formulas, l replacing g/n^2; and if R revolutions are counted per minute

$$n = \frac{2\pi R}{60}, \qquad l\,R^2 = \frac{900\,g}{\pi^2}.$$

The length of the pendulum to beat the second, with R = 30, is fixed by Act of Parliament at L = 39·1393 in, about L = 0·994 m; so that with l in metres, L R^2 = 900 × 0·994 = 894·6, but with l in inches, L R^2 = 39·1393 × 900 = 35225, from which a table can be constructed, or a setting on the slide rule, giving l corresponding to R.

Thus with R = 20,000 in the gyro-compass, L = 10^{-4} × 2·2365 cm, or 10^{-5} × 8·806 in.

When R is small, a return is made to the period T, seconds, and then $l = \frac{1}{4}$L T^2.

(To be continued.)

THE WORKS OF MESSRS. MARSHALL, SONS AND CO., LTD., GAINSBOROUGH.

(Concluded from page 641.)

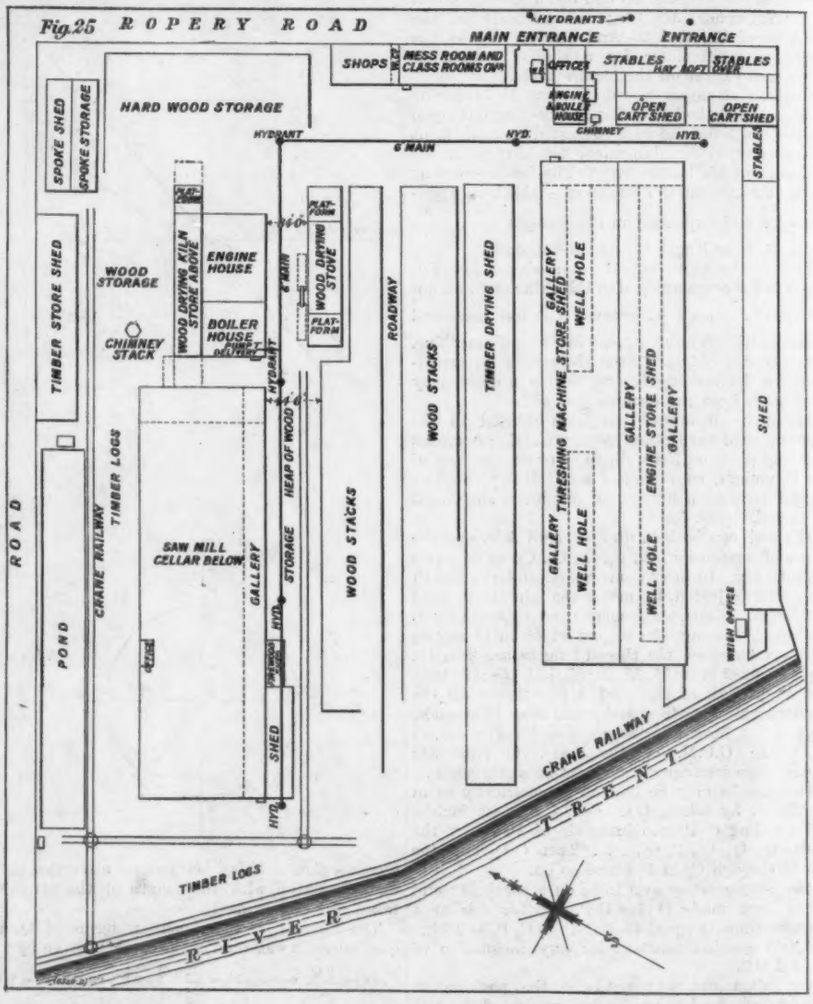
THE TRENT WORKS.

THE Trent Works, of which we give a plan in Fig. 25, herewith, is devoted to woodworking. It faces the River Trent, and timber is brought to it by boat from Grimsby, &c. These works generate their own power. We shall first deal with the power station, and then follow the course taken by the material in passing through the shops. The boiler-house contains three Marshall-Heine water-tube boilers of 125 h.p. each, fired by hand with the saw-mill refuse, which is brought to the stoke-hold floor by a belt-conveyor. Coal is only used in the event of a shortage of refuse from the mill, or when power is needed at night. Next to the boiler-house is the generator-room, in which are two Marshall-Crompton direct coupled sets, each of 125 kw. capacity, and generating direct current at 220 volts. The engines have cylinders 12 in. and 21 in. by 26 in. stroke, and work with steam at 150 lb. per square inch. A 10-ton overhead crane runs over this engine-room.

The wharf on the riverside is 675 ft. long and is laid with a standard gauge track, on which run two locomotive steam cranes, one of 5-tons, and one of 6-tons, capacity. Timber is received on the wharf by these cranes, and is sent to the saw-mill or if the length is not as required, is first cut under a large reciprocating cross-cut saw working in a lean-to outside the mill building. As in the Britannia Works a 2-ft. tramway runs through the buildings to facilitate the handling of the timber, and the finished wood-work. There are two drying-stoves on the Erith system. One measures 139 ft. by 20 ft., and is used for hard woods; the other, 105 ft by 30 ft. wide, is used for soft woods. These are outside the mill building in the yard. With this provision for artificial seasoning the long period of natural drying formerly essential is cut out, and the stocks of timber carried are consequently much reduced. The timber is cut up in the mill as received, and is then dried out between cutting and finishing. The mill building is 325 ft. long with two bays of 50 ft. each; on one side there is a gallery which is utilised for saw-sharpening machines, tool-grinding, brazing, spoke-turning, and other work, and partly as a stores.

Logs, on being brought into the mill from the

Fig. 25.



cross-cut referred to above are handled on a large Ransome horizontal band-saw, taking timber up to 5 ft. in diameter. This cuts them into planks. Close by is a long-table circular saw-bench for dealing with heavy timber. In succession as the work proceeds down the shop, it is handled by the usual class of wood-working machinery, such as mortising, tenoning, thicknessing and other machines. All the wood-work components of the thrashing machines, &c., built at the Britannia South-Side works are cut and completely finished here, as far as may be, only a very small amount of fitting being left to be done at the actual time of assemblage. The parts are turned out in bulk, and are stacked neatly during and between operations, as will be seen in the view of this mill which is given in Fig. 26, opposite. There are a number of special machines in the shop, such as, for instance, one intended for finishing the felloes of wheels, both inside and out, at one setting, and a machine for cutting the V notches in the shaker-grids for thrashing-machines.

THE TRENT WORKS OF MESSRS. MARSHALL, SONS AND CO., LTD., GAINSBOROUGH.

FIG. 26. SAW MILL AND WOOD-WORKING SHOP.

FIG. 27. FINISHED WOOD STORE.

This machine has a cutter made up virtually of several circular saws, like a compound milling-cutter. The cutter profile is V-shaped, and after the setting and cutting of the first notch in a bar, this notch serves as a gauge for the next, and so on, each notch as cut being moved up on to a vertical spacer-gauge set to bring the bar to the right position for cutting the next notch. In an annexe to the mill is a Ransome tonguing and grooving machine. This was a war introduction for manufacturing ammunition-boxes on a large scale.

Before leaving this building, mention should be made of the method of driving. Every machine-tool on the floor is electrically and independently driven. All motors are in a basement extending under the whole shop. The conveyor, taking the refuse from the mill to the boiler-house, which runs the whole length of the shop in the basement, is worked by nothing more than a 4½ h.p. motor. Cross-belts carry waste from points on one side or the other to the main conveyor. A good deal of the wastage is of the thicker sizes. This is cut into rectangular blocks for paving the shop floors. Also a large proportion of the shavings is salved for use in packing.

The produce of the wood-working shops is packed on the tramway trucks, which are run into the finished wood store, Fig. 27, annexed, where a stock is kept of all components in regular use. The trucks are hoisted bodily with the load to an upper floor, and are there run off along tracks to the stacking points. Every stock of parts is neatly stacked and ticketted, and the floor is admirably laid out for quick reference to any particular item, each position being marked with stencilled reference initials, &c., issues and stocks and other particulars. The store is heated with low-pressure steam from a special boiler. The whole of the wood-work needed to keep the South Side works and its wood store supplied is issued as required from these main stores at the Trent Works.

Other buildings at the Trent Works are being adapted for storage work, though at present partly used for patterns and other purposes. A large

area in the yard is usually utilised for the storage of pig-iron, a considerable proportion of the requirements of the Britannia Works having formerly come in by boat. Latterly the supply has been almost altogether by rail, and in this case is run into the foundry direct. At the Trent Works are also several science and art class rooms. These we refer to below.

CARR HOUSE WORKS.

The Carr House Works are undergoing alterations and enlargement. During the war they were occupied with the construction of aeroplanes. They are now being turned over to their new duties, and when completed will form a valuable relief to the Britannia Works. It is the intention to do all painting and packing there for engines and machines, and to form a store for finished sets, pending selling and despatch. It should be remembered that business of the nature of that carried on by Messrs. Marshall is, to some extent, seasonal, and their long experience enables them to gauge the trade, to a certain degree, in advance. It is the custom, therefore, when possible to build up a reserve of machines which it is known will be required at some time in a proximate season. This not only enables prompt deliveries to be made in spite of a rush of orders, but evens out the work factor for the year on the shops. The system necessitates a considerable amount of storage space, and this, till the Carr House Works were built, was rather limited. The present shops consist of three bays and an independent loading shed. The three contiguous bays are at present used for painting and finishing. Ultimately the accommodation will be as follows: There will be first of all the two present 80-ft. bays, one 250 ft. and the other 200 ft. in length, covered by Belfast roofs. These will be used as finished stores for machines. Adjoining is a shop 40 ft. by 225 ft. by 27 ft. to the eaves, furnished with a 3-ton electric overhead crane. This shop, which was built during the war in the short time of two months, will be ultimately used for a paint shop for thrashing machines, &c. The painting of portables, &c., will be done in a new shop, now in course of construction, alongside this building, the present outer wall being demolished throwing three bays into one shop. The two new bays will be 62 ft. by 150 ft. and 45 ft. by 150 ft., the latter to be subsequently extended lengthwise. Transversely at the end of these two bays will be a low-roofed paint stores. Beyond these bays again, it is intended to add considerably to the storage room under cover.

The Carr House site is bounded on one side by the Great Northern and Great Eastern Joint Line, and a siding runs into the works, alongside the present loading shed, with a turn-out into that building. This shed is an excellent building, with two tiers of lights in the side and a Belfast type roof. It measures 210 ft. by 44 ft., and is furnished with an 8-ton overhead crane and a weighing machine with a 20-ft. table. Electric capstans are fitted in and outside the shop, by which the wagons can be handled, obviating the use of a shunting engine. There is a substation at these works, with a Bruce-Peebles motor converter, converting the 6,600 high-tension supply to 220 volt direct current for use in the shops.

TECHNICAL INSTRUCTION, &c.

At the Britannia Works and also at the Trent Works there are science and art laboratories and class-rooms, and courses of technical instruction are carried on under the regulations of the Board of Education, South Kensington, &c. The school work is divided into three sections, engineering, commercial and art. The work of the first is arranged in junior and senior courses of which the former occupies two, and the latter three, years. The first year of the junior course takes practical drawing, English and arithmetic; the second year, preliminary mathematics, geometry, mechanics and physics. The senior course provides instruction in the first year in engineering drawing, engineering science, practical mathematics, and these subjects in more advanced stages, are continued through the second and third years. The ordinary class work and drawing is done in rooms provided at the Britannia Works. The mechanics and physics classes are taken at the Grammar School laboratory. Engineering science is taken at the mechanical laboratory, Fig. 28, below, at the Trent Works. In connection with the latter is an experimental steam plant similar to those supplied to various universities. There will also be installed before long an experimental oil engine. The steam installation is very completely fitted up and consists of an 8 n.h.p. girder bed compound steam engine, and an independent locomotive-multitubular boiler working at a pressure of 150 lb. per square inch. The engine has a low-pressure cylinder, 9 in. diameter, and a high-pressure cylinder, 5½ in. diameter, with a stroke of 12 in., and runs at a speed of 150 r.p.m. It is fitted with "Marshall" valve-gear on the high-pressure side to the steam and exhaust valves, and with Meyer gear on the low pressure side. The engine may be worked either with high or low-pressure cylinders as simple engines, or compound, condensing or non-condensing. The high-pressure side is fitted with "Marshall" governor and automatic expansion gear. A "Pickering" governor is arranged to control the low-pressure side, or both the high and low-pressure sides. The indicating and measuring gear is very complete. The engine is very similar to one lately supplied by Messrs. Marshall's to University College, Cardiff, a description of which was given in our issue of the 8th inst.*

FIG. 28. MECHANICAL ENGINEERING LABORATORY.

The boiler is fitted with a superheater of the usual smoke-box type arranged so that it can be put out of use when superheated steam is not wanted on the engine. The boiler equipment includes a Pearn vertical feed-pump, &c.

The commercial classes, covering English, French, arithmetic, book-keeping and shorthand, are conducted in rooms at the Trent Works, as is also a class for wood-carving. Art classes are taken in excellently arranged rooms at the Britannia Works.

Speaking generally the educational courses are of a decidedly practical nature. Practical drawing, for instance, includes the freehand drawing of parts of machinery. Workshop mathematics cover the ground required in the shops, testing, &c. In the same way the practical side is kept to the front in mechanics and physics. In the matter of heat and heat engines and machine construction, not only is the laboratory well equipped, but the instructors have to assist them the long experience of the firm in the design and production of a large range of modern engines of a high standard, examples of which are always passing through the shops.

WAR WORK.

We do not propose to give any lengthy account of the valuable work done during the war by Messrs. Marshall, but as many of the shops were put to completely new uses, and the effect of this has not as yet wholly disappeared, a short reference to the work must be made in order to explain the state in which some of them are at the present time. The normal production of the firm was either completely suspended or greatly reduced in quantity, and all sorts of munitions were substituted. Naval gun-mountings completely occupied the large erecting-shop. Altogether 1,597 sets were turned out for 4-in. guns, the record being 123 sets in one month. Two-and-a-half million fuses complete were produced, as well as 800,000 shells, 12,000 trench pumps, and so on, but these were not the most important items. The shops were also engaged on the manufacture of Mark IX Tanks, while the Carr House Works built aeroplanes. The saw-mill and wood-working department turned over completely from their regular work to the manufacture of military vehicles, of which 8,000 were produced including G.S. wagons, R.E. limber wagons, Maltese carts, &c. Components embraced artillery wheels, steel lorry wheels, wagon fittings, &c. The steam-engine work included 5-ton traction wagons, traction-engines, rollers, &c., for war zones, boilers, chemical and engineers' plant and machinery of too miscellaneous a character to detail. About 2,000 of the firm's employees joined up early in the war, but the working force was subsequently augmented by about 1,000 women in the shell and fuse departments. These have, of course, been demobilised, and practically all the men have now been released from military duties. The work of re-arrangement, however, takes time, and is not yet quite completed as we have indicated.

FIRE PROTECTION.

A carefully-organised fire-protection system is maintained at all the works. In a central position between the north and south sides of the Britannia Works there is a fire-station, which contains two Merryweather steamers, one capable of delivering 450 gallons, and the other 200 gallons, per minute, a reel cart, smoke helmet cart, and other modern appliances. Telephone connection is maintained, with all the watchmen's stations in the works. At the Trent Works a 500-gallon Worthington pump always under steam, is provided in the boiler-room, pumping direct into the fire mains which are laid over the whole area. At the Carr House Works there is a fire-station on the side of a pond, with a Shand-Mason steamer, capable of delivering 350 gallons per minute, ready with its suction connected to the water. If required outside the station this

* See page 612 *ante*.

can be quickly disconnected and the engine pulled out of the building.

The fire staff consists of one superintendent, one captain, five engineers, and 19 firemen. These are divided into two working brigades, one being responsible for the Britannia and Trent Works, and the other for the Carr House Works and the Lea Road power-station.

Ambulance Brigade, &c.

The works' ambulance brigade consists of 36 men and one trained nurse. There are three ambulance-rooms on the works, the central one being the nurse's headquarters. First-aid boxes are placed in various parts of the works.

Canteen and Welfare Work.

Although in Gainsborough most of the employees are within a few minutes of their homes, extremely good canteens are provided at the works. That at the Britannia Works is naturally the largest. This canteen consists of two halls separated by a large kitchen and service section. One hall seats 500, and the other 300. The kitchen is of the most elaborate description with steam heat and gas fires. It will serve meals for 400. The serving windows run down the side of either hall for some distance, so that congestion is avoided. The employee purchases a ticket at the ticket-office on entering, according to the class of meal he wishes to partake of, a menu with prices being posted up near the entrance. Adjoining the halls there are cloak-rooms, rest-rooms, lavatories, &c. The boiler is fired from outside the building. The canteen at the Carr House Works has only recently been finished. It seats 300 and is also well equipped. Both these canteens communicate with the street only, so that the employees have to leave the works at meal-times. At the Trent Works and at the Lea Road Power Station, which is described below, well-equipped mess-rooms are provided. There are also in connection with the works the usual sports clubs, band, &c.

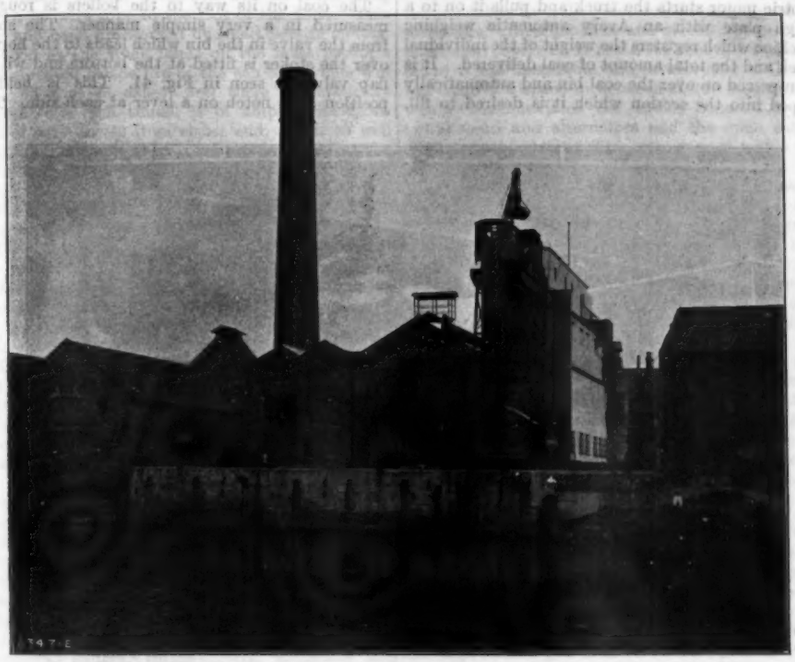


Fig. 35. Lea Road Central Power Station.

Fig. 36. Coal Hoist.

Fig. 37. "Grisly" over the Coal Bin.

Lea Road Power Station.

With the exception of the power required by the Trent Works, and that supplied at present by a station in the South Side Works in course of abolition, the electrical power required is generated at a central station, of which we give illustrations in Figs. 29 to 34, Plate XXXVIII and Figs. 35 to 44 on the present page and pages 674 and 686. A key plan is given in Fig 31, Plate XXXVIII. In this, (1) represents the coal hoist; (2) the boiler-room floor; (3) the battery of boilers; (4) the economisers; (5) the fan room; (6) the chimney; (7) the generator room; (*a*) is the entrance archway; and (*b*) a mess room.

The power station, of which an excellent idea may be obtained from the view, Fig. 35, and the sectional elevations, Figs. 29 and 32, is situated on the banks of the Trent, ¼ mile to the south-west of the works. The main building is of red brick, with the coal bin of ferro-concrete. A river wall had to be constructed, which was 32 ft. from foundations to coping. This was anchored back by ties 35 ft. long to concrete blocks 9 ft. by 4 ft. by 2 ft. The station building is thoroughly well lighted at all points for convenience of operation and for the use of the staff. In putting up this station, Messrs. Marshall were fortunate enough to find a good solid bed of clay, which is rare in this neighbourhood. This saved a considerable amount of work, as it was anticipated that piling would be required. No piles, however, were used in any portion of the work. Fig. 30, Plate XXXVIII, gives a plan of the boiler-house.

The current generated at this station at a voltage of 6,600 alternating current, is transmitted to the works, and there transformed by Bruce-Peebles motor converters to 220 volts direct current. The generating plant consists of two 1,500-kw. "Ljungstrom" turbines, shown in Fig. 43, page 686,

supplied by the Brush Electrical Engineering Company, Limited, of Loughborough, with surface condensers, air pumps, circulating pumps and air filters. The generators are three-phase, star-connected with the star point earthed through the resistance. The turbines run at 3,000 r.p.m., and are supplied with steam from four Babcock

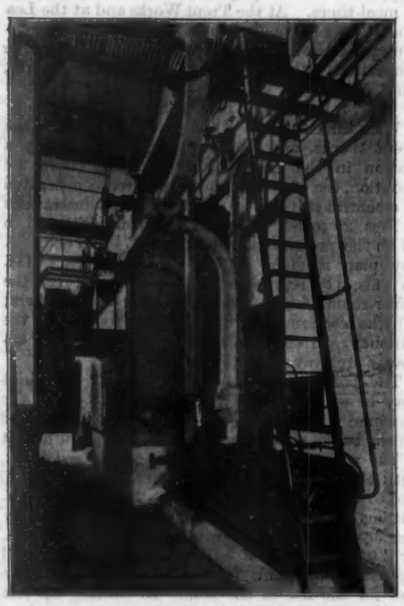


FIG. 38. BOILER FEED PUMPS.

water-tube boilers, each with 3,580 sq. ft. heating surface. Each boiler is capable of producing 12,000 lb. of steam per hour normal evaporation at 200 lb. per square inch steam pressure, and superheated 250 deg. F. The boilers are fitted with chain grates of the latest pattern and drop links, as the fuel used for these boilers is of inferior quality, having a calorific value of 10,000 British thermal units as delivered. Eighty-two per cent. of the fuel is under ¼ in. diameter, and the absolute ash percentage is 26·2. A view of the boiler room is given in Fig. 41, page 686, while the piping, &c., is well shown in Fig. 42. The boilers are fed by a Weir single-series centrifugal turbine pump, and a Pulsometer Company's six-series electrically driven centrifugal pump. A view of the feed pumps is given in Fig. 38, above.

A battery of Green's economisers, each 320 tubes, and scrapers, is fitted at the back of the boilers, each economiser being driven by a separate motor. Dampers are so arranged that either economiser can be worked with any two boilers. As two boilers are ample to steam each turbine at its full load, this arrangement is very convenient. Electric hoists and runways are provided over the economisers for lifting out any section which may require repair. Water service pipes are provided both at the front and rear of the boilers for washing out. The feed pipes are arranged so that the pumps can deliver direct to the boilers without going through the economisers, if required. The make-up feed is supplied by a Caird and Rayner patent evaporator, capable of producing 15 tons of condensed water per 12 hours. The current for the auxiliary motors to drive the stokers, feed pumps, electric hoists and crane, is provided by two small Bruce-Peebles converters in the corner of the turbine-house, which reduce the current from 6,600 volts alternating current to 220 volts direct current

The coal and the ashes are dealt with as follows. The coal is lifted from the barge or from the coal cellar by means of a 30-cwt. electric crane operating with 1-ton grab, to be seen in Fig. 35. This lifts the coal on to a platform (see Fig. 36) 42 ft. above the ground level, on which is situated a hopper into which the grab discharges its load. From this hopper the coal is fed into a truck which holds about 10 cwts. The truck runs on a road over a reinforced concrete coal bin which will hold when full about 600 tons. The roadway over this bin is fitted with a "grisly" (Fig. 37, page 673), to prevent large lumps falling into the bin should any be present in the coal. The road falls so that the incline is with the load and against the empty truck. A small electric motor starts the truck and pulls it on to a weigh plate with an Avery automatic weighing machine which registers the weight of the individual truck and the total amount of coal delivered. It is then passed on over the coal bin and automatically tipped into the section which it is desired to fill.

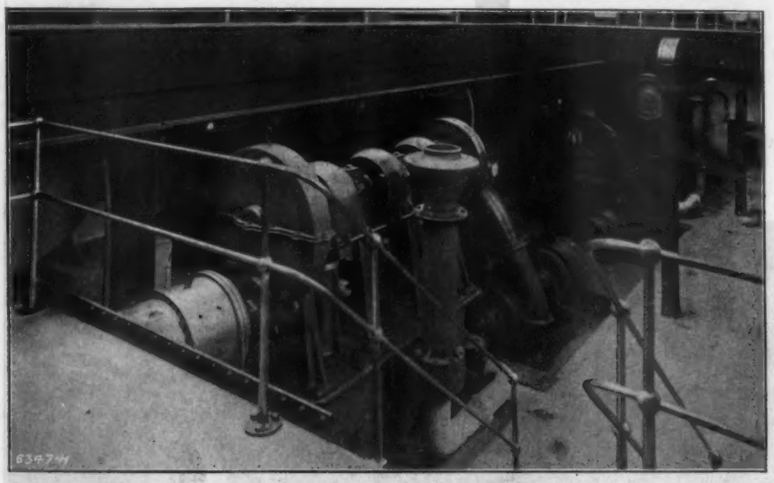


FIG. 39. AIR AND CIRCULATING PUMPS.

FIG. 40. BACK OF SWITCH-BOARD.

This coal bin is constructed of ferro-concrete on the Hennebique system. Sections of it are given in Figs. 33 and 34, Plate XXXVIII. It is 20 ft. deep and towards the bottom there is a wrought-iron 18 in. pipe which traverses the whole length of the bin. This pipe is so fitted that air can be admitted into the bottom of the coal from the outside, if required, and from this pipe five risers go to the top of the bin. In these risers electric thermometers are fitted which will operate a powerful gong, if a 2½ deg. F. rise of temperature occurs. As, however, the coal is always being drawn from the bottom of the bin by the valves which feed the hoppers of the boilers, it is not anticipated that any trouble from spontaneous combustion will arise.

The coal on its way to the boilers is roughly measured in a very simple manner. The shoot from the valve in the bin which leads to the hopper over the stoker is fitted at the bottom end with a flap valve, as seen in Fig. 41. This is held in position by a notch on a lever at each side. The top valve is opened, the shoot filled up to the top, and the top valve closed. The bottom valve is then opened and the coal between the two valves is admitted to the hopper. This space has been calibrated in position with the actual coal in use, and the coal accurately weighed. As it was found that the measurements only varied from 1 lb. to 2 lb., the lever actuating the bottom valve is con-

nected to a counter which registers the number of discharges admitted to the boilers. In this way the amount of coal fed into each boiler can be ascertained very accurately.

The ashes are discharged by the damping lever into an iron ash pit lined with firebrick. The ash tunnel at the back of the boilers is fitted with rails in a manner similar to the coal bin, the truck being drawn by wire rope to the foot of the hoist. This rope and hoist are worked by small electric motors. As soon as the truck lands on the hoist platform it is elevated to the top of the ash bin (which will hold 45 tons of ashes) and there automatically tipped. The ash tunnel is of ample dimensions and of easy access from either end, and is so well ventilated that even in winter, without feeling the walls of the ash pits it is scarcely possible to tell which boiler is working. Water service is arranged in the ash pit so that each truck can be slaked before it is taken up the hoist.

The draught for the boilers can be arranged to suit the quality of the coal and the weather by means of a "Davidson" fan driven by an electric motor, the discharge is made into a centrifugal passage round the base of the chimney. This is well shown in the plan of the boiler-house given in Fig. 30, Plate XXXVIII. The passage at the base of this chimney has at three points of its circumference an opening, 3 in. wide, and any grit left in the products of combustion is discharged through these openings into settling chambers at the back. Any debris thus deposited can be readily removed through an ordinary flue cleaning door by barrow. This arrangement has proved very satisfactory. The chimney is 8 ft. diameter inside and 110 ft. high. Arrangements are also made for direct natural draught, also for draught through the economisers without the fan, and draught with the fan. The fan is sufficiently powerful to give a draught of 2 in., if required.

To ensure correct working of this installation, recorders, gauges, thermometers, ammeters and voltmeters are fitted at all points where necessary, such as the inlet and outlet to the economisers, &c. A recording temperature gauge is provided at the base of the chimney, a recording pressure gauge on the steam main close to the branch leading to the turbines, recording CO^2 and temperature gauge, superheat thermometer, continuous CO^2 recorder in front of two boilers visible to the stokers, gauges to the circulating pumps for suction and delivery, and so on.

The water for this station is provided by means of two 4-in. centrifugal pumps, which deliver into an overhead cast-iron tank. This tank is fitted with a rough sand filter and floating suction. It supplies water for the evaporator, circulating pump bearings and fan bearings; also the air filters. The water from this tank can be run off, and it is arranged so that the filter is practically self-cleaning by reversing the current when running off the filter. The water can be discharged either into the suction main for the circulating pumps or the delivery main, or the boiler blow-off main, so that in the event of any of these mains requiring flushing, this can be done by discharging the water from the tank.

The condensing plant situated under the turbines consists of surface condensers supplied with water by 14-in. Pulsometer Company's centrifugal pumps connected to a cast-iron main which passes along a tunnel to the suction basin by the river. The delivery main from the condensers passes along the same tunnel (Fig. 29), and these mains are both arranged (as are all the other mains) so that every joint is easily accessible. The water coming in from the River Trent has to pass through a rough screen, and through two screens each with ¼ in. mesh, to prevent weeds, &c., passing through to the pumps. These screens can be hoisted clear of the water and cleaned by a set of jets arranged on the hoist tower. The discharge pipe is branched and embodied in the concrete work of the suction basin, one or the other of the branches being used according to the tide. The pipe tunnel is sloped to ensure good drainage. The air pumps for the condensers, Fig. 39, are of the Edwards type, driven by a separate motor. A pump to deliver the condensate up to the Lea recorder on the switchboard platform, is also driven from the crankshaft of the air pumps.

The switchboard, front and back views of which are given in Figs. 44 and 40, was supplied by Messrs. Reyrolle and Co., and is of the Ironclad type complete with isolation doors and synchronising panel. The whole protection casing is earth-connected with the water screens in the river, which make a perfect earth plate. The switchboard is fixed on a floor over the entrance of the station. The high tension cables from the generators to switchboard are three-core, with Merz-Price and overload protection, paper-lead covered. Beneath the floor of the switchboard is the mess-room and lavatory for the staff, but there is a space in between of 2 ft. 6 in. to 3 ft. which accommodates the cables connecting the switchboard and alternators and the main cables leading to the street. This arrangement makes the cables easily accessible though out of sight.

The cables for the plant were supplied by Messrs. Callender. The main cables are six-core, 0·075 sq. in., insulated with inner paper, lead covered, and steel armoured. Merz-Price and overload protection gear is fitted. The cables are laid in stoneware troughing with bitumen to the different points in the works where the rotary Bruce-Peeples converters are fixed. The sub-stations are connected with the power-station by a ring main.

The power station is operated by four men and two women switchboard attendants. It is erected on half the land available, so as to allow for extensions of the plant, which are even now being considered. The extension would take the form of duplication, the present coal hoist and bin-house forming the central features of the whole plant.

Power Distribution, &c.

High-tension alternating current is brought into the Britannia Works to three sub-stations, each containing two 750-kw. Bruce-Peebles motor-converter sets, converting to 220-volt direct current. These sets are fitted with Davidson washers for the air for cooling and keeping out the metallic dust. All high-tension gear is fitted with either Merz-Price or Merz-Hunter protection gear. The direct-current cables are laid in various ways. In the offices the Kalecco system has been adopted. In the boiler departments the cables are armoured, laid direct in the earth, with the tube protected where it emerges from the ground. Motor starters for the shafting are placed as a rule now in the sub-stations, as in the smiths' shop, for instance, and form part of a remote-control switchboard.

We have had to make constant reference to the crane power of the works. There are altogether 120 electric travelling cranes, about 100 electric jib cranes, and a large number of hand jib cranes, hoists on runways, &c. The overhead cranes have three or four motors each. All the cabs are made the same size, and are fitted up alike, so that an attendant can be transferred from one to any other as necessary. All shoes, tapes, controllers, &c., are alike, making for expeditious repairs and only a comparatively small stock of spares. As already mentioned, the line shafting is usually driven in lengths of not more than 50 ft., with individual drives to the heavier tools. In all about 1,000 motors are in use for machine tool driving, &c., averaging 15 brake horse-power each. The main lighting of the works is by half-watt lamps, 500 c.p., of which there are over 1,000 in use, and 5,000 smaller lamps, as well as lamps to such machines as require them.

THE IRON AND STEEL INSTITUTE.

(Concluded from page 644.)

Some Defects in Electro-Deposited Iron.

The first paper taken in the afternoon of Friday, the 7th inst., dealt with "Some Defects in Electro-Deposited Iron," by Mr. W. E. Hughes, who read it in abstract. It stated that electrolytic iron was liable to suffer from a number of defects that may render its use dangerous and make it unsuitable for engineering purposes without separate heat treatment. These defects arise from causes which could be largely eliminated by efficient control and conduct of the deposition process. Electrolytic iron was often far from being the pure product it was usually considered to be, and consequently could not be taken as pure for the starting point of research work. Electrolytic iron was not necessarily hard or brittle; the often expressed opinion that hardness was due to included hydrogen was subject to question.

Dr. Stead said it would be remembered that he and Professor Carpenter had contributed to the Institute a paper which had been read at the Brussels meeting on the crystallising properties of electro-deposited iron, in which they had referred to the peculiar properties of that iron. In thick iron no large crystallisation had developed, whilst it occurred in thinner pieces. Dr. Stead here showed a piece of a large slab; this was heated to 1,000 deg., when very large crystals were revealed. In that sample, all the peculiarities the author had referred to were illustrated. It consisted of three thicknesses united together at two junctions and evidenced the inclusions mentioned by the author. The parts were easily stripped. On one side of each slab there was a layer of perfectly pure iron as brittle as glass, and away from that the material was as tough as copper. A second sample Dr. Stead exhibited was bent over after polishing; it showed the brittle part broken up, also longitudinal fractures. In iron obtained under the same conditions, with the same electrolyte, one observed different structures. On heating one end the material became highly crystalline; the critical point was 860 deg., about 50 deg. below that of ordinary iron. Why was there this difference in the critical points? He thought the paper a valuable one which would lead to further research work to find out why electrolytic iron varied so much as it did.

Mr. J. H. Whiteley stated that when etching with the cupric reagent, if this were carefully effected, the grain boundaries would stand in relief and appear slightly whiter than the rest. On heating the electrolytic iron to 900 deg. and cooling it rapidly there occurred a great growth of crystals, but the boundaries did not disappear; if cooled slowly they disappeared.

Mr. Hughes stated that he had no experience in regard to the heating of electrolytic iron which had been referred to by Dr. Stead; he had carried out electric deposition, and he thought it was interesting to point out what he had seen in the process. Personally he believed the matter resolved itself in one of impurities in the iron, a point which had probably scarcely been realised by those who had dealt with it.

Note on the Ball Test.

The second paper taken at the same meeting dealt with the ball test and was contributed by Dr. T. Baker and Mr. T. F. Russell. It was read in abstract by the former and we publish it on page 698 of the present issue. It reviewed the work of former experimentalists in the matter of the ball test, and gave the formulas used in connection with it.

Mr. H. Moore, who opened the discussion, said the paper was a valuable one; it called attention to fundamental features of the ball test, and confirmed and extended earlier work. Meyer's simple formula $L = ad^n$ by which the relation of load to diameter of impression was correctly indicated for a ball diameter in terms of two constants expressing the properties of the material, and $\frac{4L}{\pi d^2} =$ constant for a given angle of impression for balls of different diameter threw much light on the apparently erratic variation of the Brinell number with variation in angle of impression. These formulæ could be combined into $L = \frac{kd^n}{D^{n-2}}$, where L was the load, D the diameter of ball, d that of impression, k and n being constants for the material unaffected by load or diameter of ball. It seemed probable that k expressed the hardness of the material without further strain, whilst n or $n-2$ expressed the condition as regarded cold work, or the capacity for further hardening by cold work. A formula was suggested by Benedicks for giving a constant hardness number whatever the angle of impression. The Brinell number was multiplied by

$$\sqrt[5]{\frac{D}{10}} \cdot \frac{20{,}000}{17{,}000 + L}$$

and was then supposed to give the hardness number which would have been obtained with the standard 10 m.m. ball and 3,000 kg. load. It was obvious that if the Meyer formula held, as was

abundantly proved by the results in the paper and by several previous workers, a formula of the type of that of Benedicks could not be true, since it applied the same correction to all materials, whilst with variations in Meyer's constant n, the disturbing effect of variation of angle of impression was different for different materials. It was distressing to find that the inaccurate Benedicks formula was found in deservedly popular and widely used books, although Meyer's work was published in 1908. He (the speaker) had dealt with these points in a contribution, in 1909, to the International Association for Testing Materials, to which the authors had referred. The authors had said that the coefficients a and n varied with different size balls for the same material. That was true for a, but n was a constant for the material—in a given condition—and was not affected by the size of the ball. In the authors' table II it was shown that with increasing hardness due to cold work the value of n diminished from 2,293 to 2,095 for the authors' mild steel. In his (the speaker's) experience, n was 2·39 in annealed copper, 2·53 in annealed brass, falling to 2·01 in hard worked copper, and 2·06 in hard rolled brass. In the appendix, the authors' conclusions were entirely in accordance with the facts noted in a long experience in his (the speaker's) laboratory, and followed from the laws established by Meyer. When it was a question of using balls of different diameter, all that was necessary to obtain comparable results was that the respective loads should be proportioned to the square of the diameter of the ball. Thus, a load of 30 kg. with a ball of 1 m.m. diameter gave the same hardness number as 3,000 kg. with a ball of 10 mm. diameter, or 750 kg. with a 5-mm. ball.

Mr. J. C. W. Humfrey confirmed the very great usefulness of very small balls; they were referred to in the authors' appendix and the development in their use was due to Mr. Moore. He (the speaker) had found them most valuable.

Mr. Baker in replying briefly to the discussion said it was fortunate Mr. Moore was present at the discussion since he had called attention to the misprint in the commencement of the paper and had put the matter right ("capacity of the metal for cold work," having to be replaced by "capacity for hardening by cold work"). The remarks which had been made with reference to the Benedicks formula were quite in order, and it was time that that formula be set aside, since it led to trouble. He quite concurred with Mr. Humfrey as to the great value of small Brinell impressions; these could be magnified with a microscope and an impression taken on a very small piece, such as thin wires, which were outside the scope of the standard Brinell machines. The appendix gave the values of hardness numbers, and with regard to the appendix it should be borne in mind that the method had limitations and due regard had to be paid to these.

The Distribution of Phosphorus in Steel between the Points Ac1 and Ac3.

This paper which was read in abstract by the author, Mr. J. H. Whiteley, dealt in detail with the diffusion of phosphorus in the various compounds of steel, with the temperatures and velocity of its diffusion, numerous micro-photographs illustrating the various phases and conditions.

Dr. Stead was glad to find that the author had proved something more about the mysterious way in which phosphorus acted. He asked whether the author had examined the parts which did not separate by reagents and whether he found that they contained phosphorus. He (the speaker) had found more phosphorus in the ghost lines than in the material between them. Other elements than phosphorus produced the ghost lines, and the experiments by Mr. Le Chatelier and Mr. Bogitch were very interesting in that direction. In his (the speaker's) former paper on blast furnace bears, he had experimented on material that was practically ferrite and phosphorus homogeneously distributed, samples of which he would be glad to send to all members interested in further research. The author's paper showed the extraordinary way in which phosphorus "jumped about" in ordinary common steel.

Dr. F. C. Thompson congratulated the author for Placing the interrelation between carbon and Phosphorus on a clearer footing; his method of determination would be found of great value. In regard to ghost lines there were the sulphur and phosphorus theories; in his (the speaker's) work he had found sulphide threads, but he received the author's conclusions with great satisfaction. The author had said that the micro-ghost-lines in mild steel plates were not entirely due to the heterogeneous distribution of the phosphorus, seeing that they still persisted in areas where an even distribution of the phosphorus had been obtained; to account for these ghost-lines, the author added, it seemed necessary therefore to infer that some other substance, which diffused with extreme slowness at temperatures below 950 deg. C., was also present in them. He (the speaker) felt that that could be put much more dogmatically.

Mr. H. Wrighton said that in the author's solution No. 2 the action was perhaps due directly to nitric acid; he explained how to use it, when a good relief was obtained, easy to photograph. With regard to the effect due to irregular phosphorus distribution, he had experimented with two nickel-chrome steels, one of ordinary purity and one specially pure, and he was able very easily to separate the two specimens.

Mr. Whiteley briefly replied, and said he had repeated Dr. Stead's experiments on ghost-lines; he had found that these contained more phosphorus than the rest of the material. He could not agree with Dr. Thompson that ghost-lines were due to sulphide inclusions. He could not find these inclusions.

Practical Notes on the Design and Treatment of Steel Castings.

The last paper taken was the one having the above title, contributed by Mr. G. F. Preston. It entered in detail into the manufacture of steel castings, and contained most useful directions for the obtaining of sound steel castings for a number of purposes. One speaker suggested that it might be preferable to say that the foundryman should be persuaded—rather than the "engineer" as the author stated—that exchange of views was of importance in regard to the production of castings and to the quality of the metal.

The Utilisation of Titaniferous Iron Ore in New Zealand.

The paper on "The Utilisation of Titaniferous Iron Ore in New Zealand," by Mr. J. A. Heskett, New Plymouth, New Zealand, was taken as read. We propose to reproduce it in full in a later issue. It dealt with the limonite deposit at Para Para, and with the Taranaki iron-sand, a combined magnetite and ilmenite. The paper gave the analyses of both, and of the pig-iron they yielded.

On the motion of the President all the authors received the thanks of the meeting for their contributions. The usual vote of thanks to the Institution of Civil Engineers for the loan of their building, and to the President of the Iron and Steel Institute concluded the proceedings.

The adjourned meeting took place in the Mappin Hall, Sheffield, on the afternoon and evening of Friday, the 14th inst., the members of the Sheffield Association of Metallurgists and Metallurgical Chemists having been invited to assist.

Professor Desch said the Vice-Chancellor had asked him to express his regrets at his enforced absence owing to another engagement. Dr. Ripper also regretted being absent owing to an indisposition. It, therefore, fell to him (Professor Desch) to welcome the Institute on behalf of the University, and this he did most cordially. The holding of an adjourned meeting in the provinces was an innovation and, he thought, a happy one, inasmuch as it would lead to the discussion of papers which could not possibly be dealt with at the London meeting. He welcomed Dr. Stead personally; their chairman was an eminent scientist, he had carried out a large amount of work, and very many younger students owed him a large debt of gratitude for the help he had always been ready to give them.

Dr. Stead expressed the pleasure he felt at presiding over the meeting, and thanked Professor Desch for his remarks. It was very encouraging to see so many young men present. Notwithstanding pessimistic remarks which had been put forward in America with regard to Sheffield twenty-five years ago, Sheffield held the premier position in steel manufacture, and the University had done a large amount of useful work in this connection. Many papers of London technical societies had been re-discussed in Sheffield, this affording a proof of the progressiveness of the Sheffield local societies.

The Properties of Iron-Chromium Carbon Steels.

Part I.—Thermal Analysis.

The first paper was the one having the above title, by Professor C. A. Edwards, D.Sc., Mr. H. Sutton, M.Sc., and Mr. G. Oishi. It gave historical data on chromium and the manufacture of chromium steels, on the work carried out in these steels by other experimentalists, and stated that the object of the paper was to describe the thermal critical points, and more especially the A 1 changes, of a number of iron-carbon-chromium alloys, as revealed when the rate of heating or cooling was very slow, and to record the effects of varying known rates of cooling and initial temperatures upon the carbide changes as well as their influence on the hardness of the material. The present work, therefore, might be considered as an extension to a fairly wide series of alloys of an investigation which was published by Greenwood, Kikkawa, and Dr. Edwards on a steel containing 6·15 per cent. of chromium and 0·63 per cent. of carbon. The present authors dealt with 29 different specimens; they gave their analyses, the Brinell hardness numbers, the carbide change on heating and cooling, the critical cooling velocities, &c. We reproduce the paper in abstract in the present issue.

Chromium Steels.

Part II.—Effect of Heat Treatment on Electrical Resistivity.

The second paper read dealt with "Chromium Steels, Effect of Heat Treatment on Electrical Resistivity." It was by Professor C. A. Edwards, D.Sc., and Mr. A. L. Norbury, M.Sc. In their experiments the authors worked with 38 different grades of chromium steels, and gave particulars of their experiments on quenching and tempering, on the resistivity of the steels in their annealed condition, on the influence of quenching temperature on resistivity, &c., and detailed the conclusions they had arrived at.

The discussion on both papers was opened by Dr. Andrew who, referring to Part II, said that in the authors' resistivity curves there was a break at the carbon to chromium 1 : 4·3 ratio, and the authors assumed that the carbide indicated by this break was $Fe_3C.Cr_3C_2$, whilst at other parts of the paper there was a different evidence. Dr. Edwards had referred to the change which occurred, in dealing with his tempering curves, at the 100 deg. point. In Mr. Andrew's paper, the occurrence would be seen to occur in nickel and other steels, and that being so, it would affect the conclusions drawn by Dr. Edwards.

Mr. J. H. S. Dickenson found that the authors' cooling velocities of steels having the ratio 1 carbon to 10 chromium confirmed his (the speaker's) own researches of the spring of last year, and this matter of cooling velocities had a great importance in the manufacture of alloy steels. He drew a diagram on the blackboard pointing out the variation in Brinell hardness numbers at various rates of cooling (in air, slowly and water quenching), using alloys with varying carbon and chromium contents. The object of using nickel was to make all the figures more alike. Large masses were fairly regularly hardened throughout, and on tempering the quality was also practically regular throughout.

Mr. H. Brearley referred to his book, written in 1902, in conjunction with Mr. Ibbotson, on "The Analysis of Steel Works Materials," and said much time had been devoted to considering whether different micro compounds could be separated chemically and he thought the results were all unreliable. One example was the Fe_3C compound. By attacking the original substance in different ways one arrived at residues which were always the same. Almost always the substance analysed had been obtained in empirical conditions. In

many instances, the effect of manganese was entirely overlooked, and in nickel chromium steels the percentage of manganese varied, this making all the difference in the tensile strength. Many of the authors' results and curves were satisfactory on the evidence given, but, of course, not all the evidence was available, and one should not draw too definite conclusions on the matter.

Mr. T. F. Russell referred to the analyses of residues he had made, and from which he obtained a definite compound. He had found the heat tinting of chromium steels the best method for detecting the minutest traces of undissolved carbides. With regard to resistivity tests, he saw that the authors had hardened and quenched from 1,300 deg.; had they examined those samples for burning? Burning might have an important bearing on the results. He (the speaker) had received a grant from the Carnegie fund, and would deal with the point in his investigation on the constitution of chromium steels.

Dr. Hatfield thanked the authors for their two most useful papers, which would be found useful in works' practice. If one wanted the maximum hardness in high chromium steels one had to quench from 900 deg. to 1,000 deg.; the authors had given the point at about 820 deg., and this required further explanation. He (the speaker) was not prepared to accept the authors', nor Dr. Andrew's, statements as to the dissociation of carbides. He had taken steel having 0·3 per cent. or 0·4 per cent. of carbon and a high chromium content, and had examined it microscopically after cooling in air and slow cooling in the furnace, and had found no free ferrite. At 950 deg. to 1,000 deg. there was a complete solid solution. If one took a very high carbon steel the resistivity was explained by the carbon going into solution. He was interested to hear Mr. Brearley's remarks as to the examination of residues, and he thought Mr. Brearley was justified to some extent. It was an empirical method for finding the contents in steel, but many data could be obtained from the residues.

Dr. F. C. Thompson found the authors' methods useful ones for arriving at the occurrences in annealed steels and agreed with their conclusions generally. There was, however, a shade of doubt as to the carbide indicated by the break in their curve Fig. 1, being $Fe_3C.Cr_3C_2$. By using Benedicks' formula for hardness determination—a formula that had received adverse criticism at the London meeting, an adverse criticism which, he thought, was not deserved at all—evidence was obtained in regard to the chromium. In the treatment some chromium passed into solution, some remainded as carbide, and it was reasonable to believe that there were two carbides present in the steel, but not easy to decide their compositions.

Mr. C. W. Kayser, in dealing with steels having 12 per cent. of chromium, had found the carbon change point at 150 deg. His own tests confirmed the authors' figures.

Professor Desch found that the authors' thermo-electrical tests were made in the right direction. If they could carry out work of a similar nature on the liquidus part, that would also be most useful, but he recognised the difficulty of the problem. He shared Mr. Brearley's distrust in regard to the dealing with residues. Mr. Russell had also confirmed the existence of a double carbide. Theoretical reasons further led to the conclusion that there was a definite compound. Resistivity experiments were interesting, but resistivity results were only satisfactory when dealing with a homogeneous solid solution.

Professor Edwards said that it was not easy in the course of a short reply to deal with all points which had been raised. The authors had not dealt so much with the analysis of carbides; they had carried their observations rather in other directions and had correlated their data with those of other workers. As to knowing whether, from the constitution of the steels in their annealed state, they could conclude as to their constitution when the steels were raised above their carbide point, no attempt had been made by the authors; they thought that could not be done. They thanked Mr. Dickenson for his remarks which confirmed their own. They agreed with Mr. Brearley that it was dangerous to draw conclusions from the analysis of residues; their work was being continued, and they hoped they had not been too dogmatic. Mr. Russell's remarks were valuable, they confirmed the authors' conclusions quite clearly with reference to the double carbide. They had not tried heat-tinting, but would do so and would no doubt find it of great assistance. With regard to the high temperature at which they had hardened their samples, they had found few evidences of the risk run in overheating or burning; if they had gone a few degrees higher they might probably have encountered difficulties. Their Fig. 3, in Part II, giving the increase in resistivity on quenching, showed good results; below 1,200 deg. the resistivity was practically the same as when quenching at 1,300 deg., the high temperature, therefore, had not disturbed the results. They thanked Dr. Hatfield for his remark concerning the saturation of high chromium steel having a moderately low carbon content. They were prepared to accept his view if they could perhaps modify it after reading it in print. One should not get into the habit of considering a steel low in carbon as not being an eutectoid compound. They showed in their diagram, Fig. 8, Part I, the change in the eutectoid with less than 0·3 per cent. of carbon. They thanked Dr. Thompson for his views which confirmed their results and those of other workers. They agreed with Dr. Desch that it would be interesting to attack the higher critical points, and they would do so if they had the necessary funds. But it was difficult for Sheffield workers to realise the difficulties which surrounded those employed in the laboratories of other cities where there were no possibilities of melting the steels. In regard to the arrangement of the carbides in chromium steels, it was such that it would not interfere with the authors' results. They were very small, not at the boundaries, and fairly well distributed.

The Structure of some Chromium Steels.

The third paper taken dealt with "The Structure of some Chromium Steels," and was contributed by Mr. J. H. G. Monypenny. The author said he worked with steels having up to 16 per cent. of chromium; he gave the grades in the temper colours; gave the Brinell hardness figures; stated that chromium lowered the eutectoid point considerably; pointed out the influence of the rate of cooling, and reviewed other features of the steels in question.

Mr. A. McWilliam referred to his former paper, written in conjunction with Mr. Barnes, in which the saturation point—and saturation was the term formerly used instead of eutectoid—was determined fairly closely for a 2 per cent. chromium steel.

Professor Edwards confirmed the author's findings in regard to the eutectoid points, and explained, by means of a ternary alloy diagram on the blackboard, the impossibility of getting all the carbides in solution in some steels.

Dr. Hatfield was, generally speaking, in agreement with the author's conclusions. The author had claimed that in a steel containing 12 per cent. to 14 per cent. of chromium and 0·3 per cent. of carbon he had a substantial eutectoid composition. He (the speaker) personally thought that was not an eutectoid. The steel, if equilibrium be obtained, will be found to be capable of holding more than 0·3 per cent. of carbon. He did not think the author's method was final. The point was an important one, and in saying this he was not in any way depreciating the paper. If one quenched from just above the carbon change point one obtained hardness at 900 deg. and still greater hardness at 950 deg. So far as he could see, the author's evidence was thermal and micrographic; he did not appear to prove the existence of the upper critical points, although he had not disproved them. The microsections did not necessarily represent equilibrium. In nickel chrome steels for such small forgings as aero crankshafts and automobile parts, there was a homogeneous and complete solid solution with no ferrite present. If the same steel were taken in a larger ingot, and was allowed to cool very slowly, over half the section would be made up of ferrite. This would lead to erroneous conclusions. He suggested to the author that the latter had dealt with relatively small pieces, with relatively quick cooling. If time were given for complete equilibrium, the carbon content would be found to be higher than 0·3 per cent. Free ferrite required temperature and time to be taken into solution. Whilst fully appreciating the author's work, he (the speaker) would be glad to hear what he had to say on these points.

Mr. H. Brearley said that with regard to the eutectoid, he was not much concerned if the carbon content were 0·3 per cent. or 0·4 per cent., it was certainly lower than 0·9. He had seen the work almost daily during all the time it had been in progress. The author had been fully alive to the necessity of keeping the steels a long time at particular temperatures and allowing them to cool very slowly. When free carbides were passing into solution they were doing so very slowly. Professor Edwards avoided drawing conclusions or giving reasons why some of the chromium steels were subject to surfusion; the author, on the other hand, had entered into the matter. All the three papers would yield some features which were of commercial value; the one by the present author was of interest to the makers of pure chrome steel for industrial uses. Steel for ball races contained from 1·5 per cent. of chromium upwards; if the author's curves were correct, and he believed they were, there was some disadvantage in using that steel for that purpose, disadvantages which were comparable to those attendant upon using high carbon steel for the same purpore.

Dr. F. C. Thompson found that where it was possible to compare the author's with Professor Edwards' papers, there was a most excellent agreement. In the author's micrograph 13D on Plate IV of a steel having chromium 2·8 per cent., carbon 1·1 per cent., etched with sodium picrate, there was clear evidence that two carbides were present; one etched dark and was, therefore, probably cementite, and the other he expected to be different; this agreed with the statement in Professor Edwards' paper No. II that in a steel of 2·5 to 1, there was an iron carbide and a double carbide of iron and chromium present. The author's Fig. 3 showing the influence of chromium on the solubility of cementite, illustrated that as the carbon increases the A1 point rises, and if this were compared to Professor Edwards' Fig. 3 there was found to be agreement also.

Mr. Kayser said they had used in their shops diagrams such as those referred to, in connection with the making of cutting tools and tapping dies, and the variation in the rate of cooling led to great differences in the degree of hardness. The author had given much information in his paper on the austenitic steels; this structure, when obtained, was absolutely ruinous in tool steels, and heating up to Ac1 did not remove it. Chromium-carbon tool steels quenched from about 1,150 deg. were of no use and had to be re-melted. The author, dealing with structure, had stated that changes of structure were precisely similar to those occurring in ordinary steels, the only difference being the higher temperatures at which they occurred, and had added particulars as to the reagent and times of etching; this, according to the speaker, depended upon the reagent used. He advocated the use of dilute sulphuric acid. He asked how the author had observed the tempering colours he had referred to.

Dr. Hatfield here added that an interesting feature was the necessity for studying these steels at very high temperatures. The addition of chromium, whilst reducing the carbon of the eutectoid increased the carbon of the eutectic.

Mr. Monypenny, in the course of a brief reply, said his paper had dealt with the behaviour of the carbide at the carbon change point, and also with the question of soaking and slow cooling. He had emphasised, further, the necessity of prolonged soaking. Some of the bars were soaked for six hours, and after that time quite a lot of carbide was left out of solution. The samples were heated to 1,000 deg. and cooled at a very slow rate, certainly not quicker than 30 deg. per hour. In a steel containing 0·3 per cent. of carbon and 11·2 per

cent. of chromium the first constituent to separate out was free carbide which formed a network round the crystals; the carbon change point had not taken place and the free carbide had come out. The micrographs on Plate II, *c* and *d*, showed the structure on cooling from 845 deg. and 895 deg. In regard to Dr. Hatfield's remarks as to the upper critical points, in steels of this type he was not quite aware as to which points Dr. Hatfield referred. He agreed with Dr. Thompson that there was strong evidence for the presence of two carbides. In steels of higher chromium content two carbides had not been identified, but in others of low chromium content there was no doubt that there were two carbides present. He was pleased to note the similarity between his curves and those of Professor Edwards'. He added that he had not yet met a pure chromium steel which was not tempered by heating to 600 deg. He had obtained the temper colours by treating small polished sections.

The Effect of Initial Temperature upon the Physical Properties of Steel.

The next paper taken was the one having the above title by Messrs. J. H. Andrew, D.Sc., J. E. Rippon, M.Met., C. P. Miller, B.A., and A. Wragg, B.Sc., who stated that they had endeavoured, by the determinations of different physical properties and their variation with changes in initial temperature, to arrive at the actual significance of these changes, and to advance a hypothesis that would satisfy all their experimental results. They experimented with five carbon steels, seven nickel steels, five chrome steels, and six nickel-chrome steels of varying composition. The paper was divided into chapters giving thermal data, dilatation results, a description of their dilatometer and its method of working, heating and cooling curves, &c. They entered in detail into the behaviour of the different steels they had experimented upon, and arrived at a number of conclusions which they set forth, but which do not lend themselves to abstracting. We reproduce this paper on page 681.

Dr. Hatfield said the authors had used all modern methods of research. They said martensite was a solid solution of dissociated carbide in alpha iron; this was contrary to the views of many others, and he was not prepared to accept it without reservations. Martensite was a solid solution of carbide in iron, probably in gamma iron. Some years ago he experimented with carbon steel, both unhardened and hardened, and found the heat evolved was almost the same as the heat suppressed on quenching.

Mr. Monypenny was pleased to read the authors' conclusion to the effect that martensite was the product formed when the allotropic change had been depressed by dissociated carbide, to a temperature at which the latter was able to exist as such in the alpha iron formed.

Dr. F. Rogers asked whether the dissociation could be partly explained by the dissociation into the elementary carbon or graphite, and whether it was possible for the austenite to be a partial solution of the elementary carbon in iron. Dr. Andrew, in putting forward his paper, had just said that they had no hardening until they had arrived at a point below 150 deg. The exact point depended upon the steel and on the speed of cooling. He could confirm this in some cases, and had stated it formerly. The critical point in commercial chrome steels in slow cooling was as low as 150 deg.; Dr. Rogers said he had carried out experiments with Mr. Kayser in which experiments he had obtained confirmation of this.

Dr. McCance said he agreed with the authors that carbide was in an enforced state of solution in alpha iron. There were two varieties of iron, alpha, magnetic and gamma, non-magnetic. One could not get gamma iron magnetic without altering its specific volume. A dilatation curve he drew on the blackboard showed a sudden contraction at the alpha-gamma change. At a stage Dr. McCance pointed out in his curve, he said Dr. Andrew stated dissociation took place, iron and free carbon being present. He (the speaker) said no dissociation took place. In chromium steel one got splitting out of the carbides at the same point. The electrical specific resistance of an alloy of two metals was higher than that of either taken singly; this was equally true of a mixture of alpha and gamma iron. Dr. McCance also pointed out how the specific resistance fell suddenly, then continued falling gradually, when the gamma iron changed to the alpha condition, the electric resistance being altered, although there was little change in the carbon, which was still in solution. He further drew a density curve and remarked that a change also occurred at the same point, 250 deg.

Dr. Andrew, in the course of his reply, said Dr. McCance had given an answer to Dr. Hatfield. The latter regarded martensite as a solid solution of carbide in iron, probably gamma iron; what did he regard austenite to be? (Here Dr. Hatfield interposed that he was of opinion that martensite and austenite were constitutionally the same) Dr. Andrew replied to this that the facts were rather against Dr. Hatfield in this, in the curves, the evidence was also against, all pointing, therefore, to the existence of two separate constituents. With reference to the question of the magnetism of gamma iron at ordinary temperatures, he had several samples of gamma iron whose permeability he had found to be practically zero. (Dr. Hatfield here asked how Dr. Andrew knew that the iron samples were gamma.) Dr. Andrew replied that if one took a solution of silver nitrate and added to it dilute hydrochloric acid, one obtained a precipitate of silver chloride; how was one to know that it was silver chloride? (Dr. Hatfield replied that you could obtain metallic silver and gaseous chlorine from the precipitate.) Dr. Andrew then stated that the same sort of reasoning could be applied to the point under consideration. Dr. Andrew was glad Dr. Rogers confirmed the low critical point of 150 deg., and had shown it to be a practical fact. In reply to Dr. Rogers' question with regard to the dissociation into iron and carbon or iron and graphite, he stated that all the evidence was against this. With reference to Dr. McCance's statements, Dr Andrew thought that the formula should be nFe_3C. rather than Fe_3C; one obtained complexed molecules such as Fe_6C_2, Fe_9C_3, &c., which break up on heating into molecules of less complexity, thus increasing the carbon concentration.

Brittleness in Nickel-Chrome and other Steels.

The last paper read was one having the above title, by Dr. F. Rogers. It formed the continuation of a paper by the same author read at the previous meeting of the Institute. Its object was to give complete details in the form of tables of analyses and test results, together with heating and cooling curves.

The discussion was opened by Mr. H. Brearley who said the subject was an important one, but that he was not convinced that the author was proceeding on the right lines. The author had given a large number of curves all containing many breaks, but it had been proved in the past that many breaks in curves could be traced to the apparatus used. Temper brittleness did not only occur in small pieces, and the speaker instanced Krupp steel used in the manufacture of armour-plates, whence could be traced the term *Krupp Krankheit*.

Mr. J. H. S. Dickenson could not follow the author in his theory concerning temper brittleness. Mr. Dickenson referred to the author's table of heat treatments, containing the impact or hardness tests, and thought the differences in Brinell hardness found by the author were unlike what he would have expected, they were outside admissible experimental error and required further explanation. Dr. Rogers was, he thought, on a sound basis when he referred to the importance of the initial temperature of rolling or forging.

Dr. Hatfield agreed with the two former speakers, and found that the author had not brought forward evidence to confirm the theory of his first paper.

Dr. Andrew referred to experiments he had carried out with high phosphorus nickel steels, having 3·5 per cent. of nickel, 0·35 per cent. of carbon, 0·45 per cent. of manganese, the phosphorus ranging between 0·018 per cent. and 0·152 per cent. His impact test results may be given as follows:—

Steel with 0·018 phosphorus, impact value...	90
Steel with 0·152 phosphorus, impact value...	1

After water quenching—

Steel with 0·018 phosphorus, impact value...	90
Steel with 0·152 phosphorus, impact value...	87

Consequently, he thought that phosphorus had a very great influence.

Mr. Monypenny, after referring to the author's curves and to tests he himself had carried out, of which he gave numerous figures, said that in nickel-chromium steels, phosphorus "had nothing to do with it at all."

Mr. Dickenson said he had not experimented with the high percentages of phosphorus which Dr. Andrew had considered, and he asked the latter how his steels had been made. (Dr. Andrew replied that they were made synthetically in the crucible, using iron phosphide.)

Mr. Kayser stated that he had obtained from the author a sample of his steel No. 9, and his (the speaker's) figures confirmed the author's.

Mr. J. A. Jones appreciated the work of the author, although he could not agree to all his conclusions.

Dr. F. Rogers, in replying, said that most of the data asked for were given in the paper. This was a pioneer paper which he wished to keep within limits, but enough detail had been given to enable the reproduction of any of the tests.

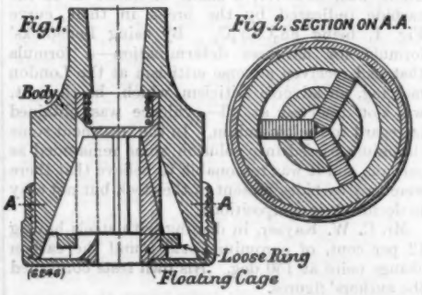
Dr Stead thought Dr. Rogers had tried to solve a frightfully difficult problem; the question was a very complex one, but he believed Dr. Rogers' work would lead to more research.

The two other papers on the list, by Mr. A. L. Norbury and Messrs. Honda and Murakami, were taken as read.

The chairman thanked all the authors for their contributions, and added that the discussions they had heard justified the holding of meetings in the provinces.

A SIMPLE DRILL CHUCK.

The annexed illustrations represent a very simple form of drill chuck manufactured by the Tangent Tool Company, Limited, of Keynsham, Somersetshire. The whole of the chuck is of steel, and the three jaws are guided by slots in a cylindrical cage, which is pushed upwards against the pressure of a light spring inside the chuck by means of the external screwed cap. The jaws thus slide on the internal face of the coned bore



of the chuck body, and are closed by the action of the conical walls. The special feature of the chuck is that the endwise pressure on the drill automatically tightens the hold of the jaws upon the drill shank, so that the grip of the chuck is independent of the tightness with which the collar is screwed up. In fact, the collar needs only to be tightened sufficiently with the fingers to prevent the drill falling out when raised from the work. Drills can, therefore, be changed very rapidly and with the minimum of exertion.

Control of Danish Imports.—According to *The Board of Trade Journal*, the action of the Danish Financial Council in advocating measures which will render all importation into Denmark dependent on the production of a certificate from the council that credit has been sanctioned for each particular consignment, has met with considerable opposition, particularly from the agricultural interests, and also to some extent from the merchants. The restrictions are also considered to be against the immediate interests of the banks, but it has been found necessary to advocate them in the general economic interests of the whole country. Recently some 700 Danish merchants proceeded to the Leipzig Fair, and the announcement that credits would probably be withheld for the purchases they made caused no small consternation. It may be remarked that very considerable quantities of marks, by some estimated at 1,000,000,000 marks, are in Danish hands, and the holders are in many cases anxious to realise what they can by buying goods in Germany.

THE STRAINING OF CIRCULATING WATER.

THE many problems in connection with the design of large generating stations, upon which this country must chiefly depend for a supply of cheap power, are now rightly engaging attention. In selecting the site for a station one vital consideration is an adequate supply of water for condensing purposes. It is not always remembered that with a modern steam turbine installation for every ton of coal burned nearly 500 tons of water have to be circulated through the condensers. This water has to be drawn from whatever source is available, usually one of the large rivers or canals. In any large power-house the lay-out of the circulating water system, and the means adopted for getting rid of the large quantity of suspended matter which is contained in all the natural sources of condensing water supply are of very great importance. Wherever the station may be situated some filtering or straining of the water is absolutely necessary, otherwise sooner or later the tube plates of the condensers become coated with a matting which increases the power required for circulating purposes, reduces the vacuum and efficiency of the turbines, and eventually necessitates shutting down for the cleaning of tube plates.

In the early days strainers with fixed grids were inserted in the suction mains, but it was found that these soon became choked and were exceedingly difficult to clean. The soft mass of leaves, straw, and the thousand and one such matters which were drawn into the meshes of the grids by the pumps, all had to be laboriously picked out by hand. With large stations it became clear that some automatic means of cleaning the straining surface was necessary. One of the first self-cleaning strainers was installed by the City of London Company at Bankside. There the straining surface is a circular disc which is slowly revolved in a vertical plane, inside a chamber divided into two compartments, one of which is in the suction and the other in the discharge portion of the system. Any solid matter trapped by the revolving disc in the suction side is washed back to the source of supply when it reaches the discharge side. Strainers of this type have done excellent work, but they have the disadvantage that they are large and expensive, more especially as little more than one-third of the total surface is operating as a strainer at any time. They further suffer from the disadvantage that it is difficult to prevent leakage between the two compartments.

Another form of automatic strainer which is largely in use is designed on quite different lines. With this type the suction is led through an open channel in the top and bottom of which are placed drums round which revolves a specially-constructed link-chain screen in a similar manner to the grate of a chain-grate stoker. The solids caught in this screen may be either brushed off or washed off by jets of water supplied by pressure pumps. The former arrangement is used at the Lots-road Station of the Underground Railways. With this type of strainer it is not possible to have a completely closed system. Large straining pits have to be excavated and must be taken down below the minimum level which the source of supply, usually tidal, may ever reach. Only a comparatively small portion of the screen is doing useful work at any time, and if jets are used for cleaning, a separate pump with its water connections is required. Pumps up to over 50 h.p. have been installed for this purpose in addition to the power required for revolving the screen. The conditions under which such a screen has to work with joints in and out of the water makes fine screening difficult.

There is another type of strainer of which we propose to give some details, as it possesses considerable merit, and does not appear to be very well known. It was referred to by Mr. G. W. Partridge, engineer and manager of the London Electric Supply Corporation, Limited, at a recent meeting of the Institution of Electrical Engineers, and is known as the "Deptford" strainer. We are indebted to Mr. Partridge for the illustrations and particulars which follow. The general arrangement of the strainer will be understood from Fig. 1, which is a sectional elevation of one of several of these strainers of 1,000,000 gallons per hour capacity in use at the London County Council Tramway Generating Station at Greenwich.

Fig. 1. SECTIONAL ELEVATION LOOKING TOWARDS OUTLET END.

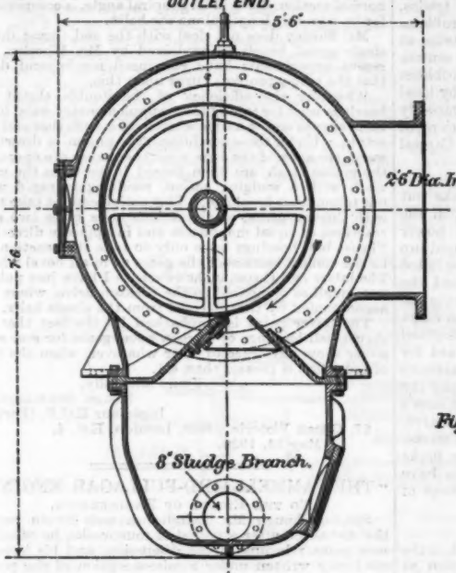


Fig. 3. SECTION AT OUTLET END.

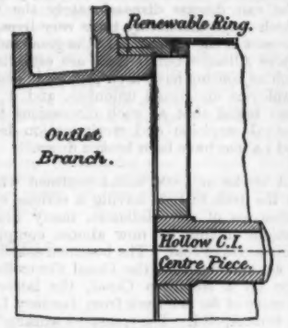


Fig. 4. SECTIONAL ELEVATION THROUGH STRAINER FOR SUCTION SIDE OF CIRCULATING PUMP.

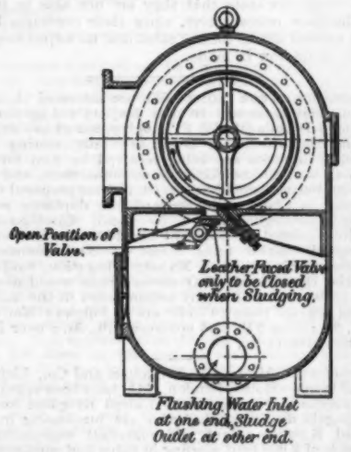
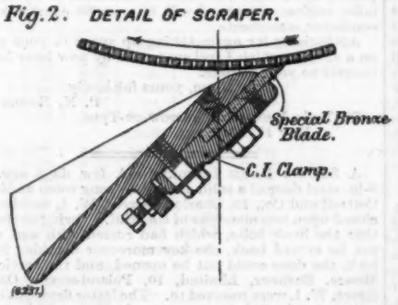

Open Position of Valve.
Leather Faced Valve only to be Closed when Sludging.
Flushing Water Inlet at one end, Sludge Outlet at other end.

Fig. 2. DETAIL OF SCRAPER.



(8331)

In this apparatus the straining surface is the outside of a perforated drum built up of gun-metal plates on cast-iron spiders, one end of the drum being closed, and the other end open to the outlet for the strained water. The drum is perforated with small holes, and it has been found that with the ¾-in. tubes now almost universally used in condensers the holes in the strainer should be not more than ⅛ in. diameter. The outside of the drum, which is of stiff construction, is accurately turned to a true cylindrical form. Bearing against the drum along its lower surface is a bronze scraper which has a chisel edge and is adjusted so as to lightly press against the drum along its whole length. In large sizes this scraper is fitted in short lengths of about 18 in. to facilitate adjustment. Details of the scraper are shown on Fig. 2.

The drum is revolved by worm-gearing from the closed end at about 3 r.p.m. to 4 r.p.m., and the solids removed by the scraper fall into a settling chamber. It will be borne in mind that as the water is usually drawn from near the bottom of a river, the solids in suspension will tend to settle to the bottom of the strainer where the water is quiescent. In the larger sizes of this strainer the drum is placed, as shown in Fig. 1, towards one side of the body in order to give ample area for the incoming water, while at the same time keeping the dimensions down to a minimum. The bearing at the open end of the drum is taken on a spigot cast on the outlet cover, details of which are given on Fig. 3. It will be seen that a renewable ring is fitted to the drum so that in the course of time any wear can be taken up by fitting a new ring without having to remove the drum. It has been found, however, that these drums will run for years without this being necessary, as the drum is adjusted from outside endwise so as to bear against the facing machined for the purpose and so prevent solids getting into the spigot joint. The lower part of the strainer is provided with a sludge valve which connects through piping to the return main.

As the whole straining surface is always at work and is thoroughly cleaned three or four times per minute, the strainer is of very small size, and it has been found that provided the total area through the holes is more than twice the area of the pipes the loss in pressure across the strainer is negligible. As regards the power required, if a ball thrust washer is fitted for the worm gearing even the large sizes can be turned by hand, so that the power consumption is very low. For sludging purposes, as the full head of the system is available, all that is normally required is to open the sludge valve for a few seconds about every 4 hours. With reference to upkeep the first of these strainers was installed at Deptford nine years ago, and has been working almost daily ever since. All that has been found necessary is to adjust the scrapers about every six months and renew the joint ring at the spigot about every three years. Four of these strainers of large size have been at work at Deptford for several years, and have been found so reliable that no by-passing arrangement is fitted.

The strainers are very suitable for a closed system, and have the advantage that they do not bring the decaying vegetable and other matter to the light of day. They may be arranged in any suitable position on the circulating system, although it is preferable to have them placed on the discharge side of the circulating pump in order to have pressure head available for sludging. If, however, it is found necessary to have the strainer on the suction side of the pump, then the arrangement shown in Fig. 4 is adopted, a simple type of valve being used to separate the straining and settling chambers when sludging is being carried out from whatever source of pressure is available. The patentee is Mr. T. M. Aitken and these strainers are being supplied by the London Electric Supply Corporation, Limited, of 25A, Cockspur-street, London, S.W., in standard sizes up to 1,500,000 gallons per hour capacity. Larger sizes are, we understand, in course of construction.

A QUEENSLAND TIN MINE.—The Sardine tin mine at Oakey Creek, about 4 miles from Ewan, Kangaroo Hills, was discovered in December, 1918, by Mr. Alexander T. Lain, of Messrs. Murhall and Lain, prospectors and mine owners of Kangaroo Hills, and since then results of development work have proved it to be one of the richest deposits of tin ever found in North Queensland. From ore won at one spot the prospectors obtained 179 tons of tin ore which, on being crushed, yielded 62 tons of black tin, roughly valued at over 9,000*l*. A Charters Towers Syndicate obtained a working option over the property, and started work on September 25 last. Since then they have raised from sinking a shaft 6 ft. by 4 ft., for 40 ft., and driving some distance at the 40-ft. and 50-ft. levels, 180 tons of ore, which is believed to be worth 30 per cent. for black tin, equal to 54 tons and worth at present market price at least 11,000*l*.

INDUSTRIAL NOTES.

A MEETING of the London branch of the National Union of Scientific Workers, the offices of which are at 19, Tothill-street, S.W. 1, was held in London on the 11th inst., when Major Church, the secretary, spoke of the scandalously low salaries being paid at the present time to scientific workers both in Government establishments and in private firms. These low salaries would be paid so long as people would take them. There must be organised protest, and where this failed, action should be taken, not by strikes, but by the professional method of the boycott of firms who underpaid their staffs. This was legal only for a trade union and accounted for the Union having registered as such. The National Union of Scientific Workers had considered a scale of minimum salaries which they believed to be fair and which they were attempting to establish. He believed that such a policy loyally carried out could be successful, but it needed funds, a large membership and an understanding with all sectional bodies that there would be no undercutting. The Union had now members all over the Empire, and its recent activities in connection with income-tax abatement had aroused widespread interest. It was not the only union, but the only national union of workers in all branches of pure and applied science, and it was anxious to establish relations with all bodies representing sectional interests.

The report dated May 12, issued by the Steam Engine Makers' Society, states that the membership is 30,000, the unemployed number 232, and the capital amounts to 310,000*l.* The report adds that the society is shortly—on July 1—to be merged into the Amalgamated Engineering Union. The Steam Engine Makers' Society was established at Liverpool on November 24, 1824.

The rules drafted for the Amalgamated Engineering Union, referred to above, are being considered. The new Union will have a membership of over 460,000, and total funds to the amount of 3,500,000*l.*, so far as is now reported. It is stated that the following societies are entering the Union:—Amalgamated Society of Engineers; Steam Engine Makers' Society; Society of General Toolmakers; United Machine Workers' Association; Amalgamated Instrument Makers' Society; Smiths' and Strikers' Society; Associated Brassfounders, Turners, Fitters, Finishers, and Coppersmiths' Society; East of Scotland Brassfounders' Society; North of England Brass Turners, Fitters and Finishers' Society; Dublin Brassfounders' and Finishers' Society; London United Metal Turners, Fitters and Finishers' Society.

The selling price of West Coast hematite pig-iron for the four months ending on April 30 was 11*l.* 7*s.* per ton, as compared with 10*l.* 5*s.* 6*d.* in the preceding four months; under the sliding scale, blast furnacemen's wages rise by 27½ per cent. to 197½ per cent. above standard.

A meeting of delegates representing the railway shop workers was held in London last week in connection with the men's demand that their conditions be standardised in the same way as those of the conciliation grades; the men also ask for machinery to deal with local questions as well as questions of a national character. A resolution was passed in the following terms: "This conference of railway shop workers having reviewed the demand put forward to the Government by the National Union of Railwaymen for the standardisation of wages on the basis of 4*l.* for unskilled workers, 5*l.* for semi-skilled and 6*l.* for skilled workers, also the principle contained in the same, namely an equal rate of pay for the same classes of work in all shops in any part of the United Kingdom as against the claim by the old crafts union for district rates, and having discussed the proposed scheme of machinery for dealing with shop workers' grievances put forward by the N.U.R. we decide to support these claims as a means to this end, namely national rates for railway shop workers, seven days' holiday with pay and machinery as laid down. We call upon all railway workers to close up the ranks of labour by joining the N.U.R."

It is reported that the Amalgamated Society of Engineers have rejected payment by results by a majority of 39,997, the ballot showing 14,170 in favour and 54,167 against.

The National Alliance of Employers and Employed, 64, Victoria-street, S.W. 1, in announcing that the annual conference this year is to take place on June 1, at Birmingham, states that extremists in labour ranks and reactionaries among employers, believe in the policy of force. The alliance stands for forbearance, and the work it has accomplished is an assurance that steadily increasing numbers of employers, and representatives of organised labour, are massing themselves with this movement, and striving for agreement over industrial problems—with good will.

The alliance, it adds, takes a grave view of the present spirit of unrest manifested in every section of the community. The price of commodities still increases, and with every rise in wages there is a corresponding increase in the cost of living. Labour blames Capital, and Capital blames Labour, but there is no wholehearted effort on the part of either side to grapple with the problem in that spirit of unity which won us the war. Housing is a case in point. Grave charges are levelled against the building operatives who are, on the one hand, accused of deliberately restricting output; on the other, builders are accused of profiteering in material and of taking advantage of the lack of housing accommodation.

The alliance justly claims to be the only organisation which can provide the machinery for a round-table conference of employers and employed of all trades, who can discuss dispassionately the vital problems which touch intimately their very lives, and strike at the root of the trouble. In the great industrial centres where Alliance Committees are established, problems such as housing have been profitably discussed by local employers and trade unionists, and it has invariably been found that at such discussions the barriers of mutual suspicion and recrimination between Capital and Labour have been broken down.

A strike of 3,000 canal boatmen which broke out on the 10th inst. is having a serious effect upon the industries of the Midlands, many firms and power stations having by now almost completely used up their stores of coal. The boatmen asked to be included in an award which the Canal Controller granted the men on a Northern Canal, the latter receiving an increase of 5*s.* per week from January 1, plus an extra 1*s.* from April 1. The transport workers' officials asked the Midland employers to grant the same award for their district and also to make it retrospective to January 1. The Midland employers agreed to pay the increase of 6*s.* per week from the date of the men's demand and declined to make the award retrospective. The men insisting upon their point came out on strike. The employers state that they are not able to make the increase retrospective, since their contracts have been carried out at former rates and no adjustment of prices could now be made.

CATALOGUES FOR CHILE.—We are informed that the Commercial Secretary to His Majesty's Legation at Santiago de Chile (Mr. W. F. Vaughan Scott), has written to the Department of Overseas Trade, stating that frequent inquiries are being received by him for the catalogues of United Kingdom manufacturers, and that a useful purpose would be served, if firms prepared to do business in Chile would forward him duplicate copies of any catalogues issued by them. Catalogues (if possible printed in Spanish) should be addressed by interested British firms direct to The Commercial Secretary, His Britannic Majesty's Legation, Santiago, but the Department of Overseas Trade would also be glad to be informed of any action taken in the matter. Parcel postage rates to Chile are as follows: Not over 3 lb., 2*s.*; over 3 lb. and not over 7 lb., 3*s.*; over 7 lb., but not over 11 lb., 4*s.*

PERSONAL.—Messrs. H. J. Skelton and Co., Limited, Royal London House, London, E.C., have been appointed sole purchasing agents in the United Kingdom for the Compagnie de Fives-Lille, who are purchasing in the United Kingdom plant and materials amounting to upwards of 2,000,000*l.* sterling in value and consisting of iron and steel material for building bridges, locomotives, boilers, electrical plant, machinery, &c., required in connection with the reconstruction and operation of their works in Northern and Eastern France.—Messrs. Buckley, Saunders and Co., Limited (E. A. Chantler), have secured the agencies for South America of the Wild-Barfield electric furnaces, and also, for the Argentine that of the A.I. Manufacturing Company's electric welding machines. Demonstration plants are already erected and working at the works in Buenos Aires. A demonstration Wild-Barfield electric furnace will also be in operation shortly in Rio de Janeiro.—Messrs. the Saunderson Tractor and Implement Company, Limited, Bedford, state that their new patent automatic lift grubber has been awarded the first prize silver medal, at the Royal Dublin Society's Show.—The High Speed Machinery Company, Limited, Regent Works, Ponder's End, N., state that they have appointed Messrs. Advance Machinery Company, 41, Lower Mosley-street, Manchester, their sole representatives and selling agents for Lancashire and Cheshire.—Messrs. D. Selby Bigge and Co., consulting engineers, Mercantile Chambers, 53, Bothwell-street, Glasgow, and 28, Victoria-street, London, S.W. 1, state that Mr. Andrew Bruce Muirhead, who has been continuously identified with their business for the past twenty years, has become a partner in the firm. The partnership will continue as hitherto under the same name, the addresses remaining also the same.—The British Piston Ring Company, Limited, Holbrook-lane, Coventry, have appointed Mr. Thomas B. Hamilton, 5, Fortfield-terrace, Upper Rathmines, Dublin, their Irish representative.

"GEAR CUTTING."

TO THE EDITOR OF ENGINEERING.

SIR,—I have read with great interest Mr. P. J. Worsley's paper on "Gear Cutting," and the subsequent discussion, at the Institution of Automobile Engineers, as reported in your issue of March 19. As an engineer who is interested more particularly in gears for rear axles, I am of opinion that Mr. Worsley has drawn a rather hard and fast line between the copying process—so called—and the generating one. Preference is given to the latter on theoretical grounds, no practical evidence being brought forward, nor indeed could there be, since, as Mr. Worsley states, no machine has yet been produced capable of generating double helical bevel teeth of the correct theoretical shape. I also think that Mr. Shirley's comparison between the Gleason and the Citroen gears, fails to bring to light a number of important points.

Any engineer who has seen Citroen bevel gears in operation cannot question their smooth running. This is obtained on a width of face equal to that of the Gleason type by adopting a proper spiral angle, which does not in any way reduce the strength of the tooth, as the smaller normal section, due to a large spiral angle, is compensated for by a greater length along the helix.

Mr. Shirley does not deal with the end thrust due to single spiral bevels as explained by Mr. Worsley, and recent experiments have convinced me beyond doubt that the whole problem turns upon this.

Whatever the efficiency of the double thrust ball bearings used for taking these supplementary axial loads, there always comes a time when wear is such that end play sets in. Under these conditions, the pinion is drawn towards the apex of the cone when the brakes are operated: the pinion teeth are then forced in between the wheel teeth with a wedging action, resulting in rapid wear, not to mention breakage. This action cannot take place with Citroen gears, as the double helix gives two axial reactions of equal magnitude and in opposite directions. Thrust ball bearings have only to take the reaction due to the conical surface of the gears as in all bevel wheels. The latter end thrust is, however, as I have just pointed out, small as compared to the Gleason drive, where it is accompanied by that derived from the single helix.

The latter point is emphasised by the fact that the thrust ball bearings of Citroen bevel gears for rear axles never show any trace of wear whatever, when the ratio of reduction is greater than 4/1.

Yours faithfully,
ROGER SCHWEICH,
Ingénieur E.C.P. (Paris).

27, Queen Victoria-street, London, E.C. 4.
May 14, 1920.

"THE CAMMELLAIRD-FULLAGAR ENGINE."

TO THE EDITOR OF ENGINEERING.

SIR,—Although Mr. Leitch has seen fit to reopen the discussion after a period of four weeks, he raises no new point relevant to the discussion, and his letter is obviously written under a misconception of the points at issue.

My previous letters gave my views on the various points, and if read with the common sense and judgment most engineers possess, will be seen to contain no inconsistent statements.

Apologising for again taking up space in your paper, on a subject which I feel sure must by now have lost all interest to your readers.

I am, yours faithfully,
P. N. EVERETT.

29, Bede Burn-road, Jarrow-on-Tyne,
May 17, 1920.

A STRONG ROOM INCIDENT.—A few days ago, the 6-in. steel door of a solid concrete strong room at Messrs. Cottrell and Co., 15, Charlotte-street, W. 1, accidentally closed upon two members of the staff. Owing to the fact that the hook bolts, which had rusted with age, could not be moved back, the key moreover breaking in the lock, the door could not be opened, and the services of Messrs. Barimar, Limited, 10, Poland-street, Oxford-street, W. 1, were resorted to. The latter firm sent to the spot several of their expert engineers, and the latter, using Barimar special cutting tools upon the door, gradually cut a passage through and released the two captives.

HADFIELD PRIZE FOR HARDNESS TESTS.—We wish again to call our readers' attention to the fact that Sir Robert A. Hadfield, D.Sc., D.Met., F.R.S., has placed in the hands of the Institution of Mechanical Engineers the sum of 200*l.*, which, with any income therefrom, may be awarded at the discretion of the Council as a prize, or as prizes, for the description of a new and accurate method of determining the hardness of metals, especially of metals of a high degree of hardness. As mentioned on page 271 *ante* a grant of 20*l.* has already been made from the fund to Mr. A. F. Shore, of New York, for a paper on "Hardness Determination" published in the Journal of the Iron and Steel Institute, and another sum of 7*l.* has been granted to Mr. J. Innes for his paper on "The Measurement of High Degrees of Hardness." The Council will consider annually all communications received, and may then award a prize or prizes, but in January, 1922, the offer of prizes will be withdrawn and any unexpended balance of the prize fund will be directed to other purposes at the discretion of the Council. Full particulars of the conditions under which prizes will be awarded will be found on page 415 of our issue of March 26 of last year. Communications should be addressed to the Secretary, the Institution of Mechanical Engineers, Storey's Gate, St. James' Park, London, S.W. 1.

THE EFFECT OF INITIAL TEMPERATURE UPON THE PHYSICAL PROPERTIES OF STEEL.*

By J. H. ANDREW, D.Sc., J. E. RIPPON, M.Met., C. P. MILLER, B.A., and A. WRAGG, B.Sc.

MOST of the work carried out upon the physical properties of special steels is not of a co-ordinated nature. Few attempts have been made to correlate and explain the various changes in the physical properties of steels due to varying initial temperature and rate of cooling. No theory which can be applied generally to all steels has yet been put forward.

Thermal data have shown that in many ternary, and most quaternary, steels, increase in initial temperature gives rise to a splitting up of the main point upon cooling into two or three distinct points, each occurring at a different temperature. These evolutions of heat generally occur at definite and constant temperatures, the effect of still higher initial temperature being to vary the magnitude of these rather than the temperatures of their evolutions. In nickel-chrome steels, for example, containing about 3½ per cent. nickel and between 1 per cent. and 2 per cent. chromium, two or three such points are obtained with certain initial temperatures.

French scientists consider that in this case the upper point is due to the transformation of austenite into pearlite or troostite, and the middle point due to the transformation of austenite into martensite; the lower point at 150 deg. C. has hardly been considered. Without at the moment discussing the *pros* and *cons* of this view, even if it is correct, it must be acknowledged that it is an interpretation of the change points rather than an explanation of their cause, and of the effect of varying initial temperature.

In this paper the authors have endeavoured, by the determinations of different physical properties and their variation with changes in initial temperature, to determine the actual significance of these changes, and to advance a hypothesis that will justify all their experimental results. The steels experimented with had the following compositions:—

—	C.	Mn.	P.	S.	Si.	Ni.	Cr.
			Carbon Steels.				
A	0·80	0·26	—	—	0·210	—	—
B	0·60	0·25	—	—	0·175	—	—
C	0·44	0·20	—	—	0·186	—	—
D	0·96	0·27	—	—	0·186	—	—
E7	1·15	0·35	0·013	0·020	0·224	—	—
			Nickel Steels.				
2	0·26	0·27	0·014	0·025	0·102	3·64	—
3	0·32	0·29	0·012	0·043	0·145	3·62	—
4	0·44	0·38	0·015	0·038	0·125	3·65	—
5	0·67	0·40	0·012	0·027	0·108	3·64	—
6	0·87	0·41	0·013	0·025	0·149	3·64	—
7	1·06	0·42	0·013	0·026	0·154	3·67	—
8	1·65	0·30	0·014	0·025	0·125	3·50	—
			Chrome Steels.				
C	0·35	0·24	—	—	—	—	1·56
D	0·62	0·22	—	—	—	—	1·67
E	0·80	0·25	—	—	—	—	1·67
F	0·95	0·25	—	—	—	—	1·68
B	1·73	0·30	—	—	—	—	1·65
			Nickel-Chrome Steels.				
A	0·36	0·18	0·019	0·042	0·084	3·56	1·37
B	0·51	0·22	0·021	0·048	0·126	3·52	1·72
C	0·76	0·24	0·021	0·053	0·112	3·58	1·64
E	1·01	0·32	0·019	0·053	0·130	3·61	1·66
G1	1·28	0·26	—	—	—	3·46	1·80
G2	1·50	0·26	—	—	—	3·46	1·80

The physical properties determined were as follows: Thermal data, temperature resistivity data, temperature dilatation data, and magnetic temperature data.

Thermal Data.—Specimens 1 in. diameter, 1 in. long, were taken; they were heated and cooled in an electric furnace in the usual way, a Carpenter-Stansfield potentiometer being used. The rate of cooling was the same for the different specimens, being one and a half hours from 1,000 deg. to 350 deg. C., after which the specimens were taken out of the furnace and cooled in air. All specimens were soaked 15 minutes before cooling.

For dilatation experiments two differential methods have been used by other workers, one in which the temperature is measured by a thermocouple, and the difference in expansion between the steel in question and the standard bar is recorded; whilst in the other, more recently introduced by Chevenard, the temperature is measured by the expansion of the standard bar, and a mirror movement in two directions is recorded.

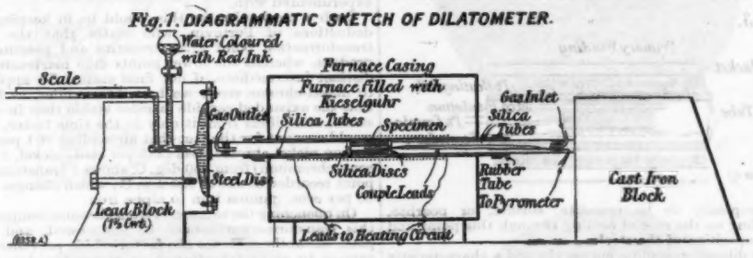
One condition essential for accuracy in all differential methods is that the standard bar and specimen must be at the same temperature. Where, as is always the case, the standard and sample have different thermo-properties and specific heat, &c., this condition is almost impossible to fulfil, excepting for extremely slow rates of working. An example of this is to be found in Honda's recent paper "On the Nature of the A1 Transformation,"* in which he exhibits curves intended to show the formation of martensite as a distinct stage in the transformation of austenite into pearlite at 680 deg. C. upon slowly-cooled specimens. His results indicated that the transformation on heating takes place with comparatively little contraction and extends over a range of from 80 deg. to 180 deg. C., whereas it is well known that this transformation completes itself in an interval of 20 deg. C. or so, even on a rapidly rising temperature.

This apparent prolongation of the point is due to the temperature of the specimen lagging behind that of the standard, owing to the fact that the former is absorbing heat whilst going through the Ac1; whilst the latter, being of nickel or cobalt, heats up in a uniform manner. If this discrepancy arises on heating, which cannot be very rapid, it is clear that it must be greatly accentuated on rapid cooling. This is particularly noticeable in his (Honda's) curve of 0·8 per cent. carbon steel cooled in air blast. It appears from this curve that the critical point on cooling is spread over a range of 200 deg. or so, during which the length of the bar is approximately constant. The effect of this is that the cooling curve crosses the heating curve. On this evidence Honda claims to prove the necessity of regarding martensite as an intermediate phase between austenite and pearlite at that temperature.

This error is caused by the contraction of the standard bar not recording the correct temperature of the specimen, as it is assumed to do by Honda. Taking his figures, he states that the austenite to pearlite change incurs a heat change of 18·2 calories, the specific heat of the standard being of the order of 0·1, and the emissivity of heat for both bars being practically the same, it follows that the standard bar must have a much lower temperature than the specimen at the completion of the transformation. This means that if a specimen passes through the transformation point, the standard bar which records the temperature, in order to give out an amount of heat equal to the thermal value of the change in the specimen, would have to cool through 182 deg. C. As both bars were cooled in an air blast they will give out heat at very similar rates, neglecting for a moment the radiation effect between one bar to another, which under these conditions will be very small. It is apparent that the end of the critical change will not occur at 450 deg. C. as is shown, but near 600 deg. C., when the cooling curve will not have crossed the heating curve. This will account for the fact that both curves meet when the temperatures of the bars are the same, i.e., near to atmospheric temperature, at which temperature this differential error is absent. This reasoning will apply to all differential methods.

A sketch of the apparatus used by the authors is shown in Fig. 1.

Fig. 1. DIAGRAMMATIC SKETCH OF DILATOMETER.



The specimen of steel to be examined was in the form of a hollow cylinder 2 in. long, ¾ in. diameter, with a ½-in. hole through the centre. This form of specimen was chosen because its short length and large diameter facilitated uniform heating; whilst its maximum thickness being ⅛ in., a uniform product was obtained on quenching.

The specimen was placed in a silica tube of 1 in. internal diameter wound externally over a length of 9 in. with thin platinum wire, which was the heating unit of the furnace employed. On the ends of the specimen, which were ground parallel and polished, two silica discs (also accurately ground) were placed. These discs were pressed against the ends of the specimen by means of two silica tubes, which served to transmit any change in length of the specimen.

This furnace unit carrying the specimen was supported on a thick concrete slab built on brick pillars not more than 1 ft. apart. One of the silica tubes which transmitted the expansion of the specimen was butted up against a heavy cast-iron block; the other tube being pressed against a measuring device which was butted to a large lead block.

The relative movement of the silica tube was measured by a hydraulic device. This consisted of a thick steel disc 8 in. diameter, having a saucer-like depression on its face; over this face was clamped a thin disc of saw steel. The space so enclosed was filled with coloured water. A pipe ran through the back of the steel disc connecting this liquid with a horizontal glass tube with a scale attached. A small reservoir with a tap was also fitted for adjusting the amount of liquid in the system. This liquid micrometer was bolted to the lead block, so that the thin steel disc was vertical. A steel disc, 1 in. diameter with a dead flat surface transmitted the movement of the silica tube to the thin steel diaphragm.

It was found that with a glass tube of about 2 mm. bore the movement of the meniscus magnified the displacement of the silica tube by 2,000 times. The sensitivity was found to be the most convenient for the work in hand.

As the result of several hundred experiments, it may be stated that the magnification of the micrometer was found to be sensibly constant over the scale length of 50 cm. employed.

The temperature of the specimen was measured by means of a platinum-platinum-iridium couple, placed, as shown in the diagram, in the centre of the specimen. As a pyrometer, a Paul milliammeter was employed, being read with a moving microscope. The scale length was equivalent to about 350 deg. C., and a series of shunts of fixed E.M.F. was employed to read higher temperatures. In this way the scale was used three times over to read 1,000 deg. C.

The pyrometer was calibrated by means of checking the melting-points of pure Sn, Pb, Zn, Al, NaCl, Ag, and Cu, and the lowest temperature by boiling water.

To calibrate the dilatometer a specimen of copper was used. This gave a fairly straight line upon heating to 900 deg. C., and retraced its path on cooling.

A silica specimen also gave a straight line, and up to 900 deg. C. there was very little loss. Prolonged soaking above this temperature was found always to be accompanied by a loss which increased with time and temperature.

When using steel specimens the results varied as regards loss on a cycle.

With chrome steels the curves generally met at low temperatures, even after running up to 1,000 deg. C. Carbon steels, excepting those of low carbon content, were very good, but nickel steel, especially with low carbon and high manganese, always showed a very appreciable loss. This loss was negligible when the steel was heated below Ac1, but on doing a cycle through Ac1,2,3 and Ar3,2,1 it appeared. It may be that the volume changes on passing through the critical ranges were not uniform in all directions.

A flexible gastight joint was made by means of tubes of thin rubber fixed on to the ends of the furnace tubes and then wired to the moving silica tubes. Through holes drilled in these two silica tubes, gas was circulated round the specimen to prevent oxidation. Nitrogen was used for some experiments. It was found that coal-gas passed over broken asbestos at 1,000 deg. C., to free it from illuminants, gave results similar to nitrogen, and was much handier to use.

Upon setting up the apparatus for an experiment, the pressure on the steel diaphragm was adjusted by tapping the cast-iron block till the silica tube pressed lightly on it. When the coloured water had reached the end of the scale the temperature was kept constant for a moment, and the cast-iron block gently tapped back till the liquid returned to the beginning of the scale. With practice this can be done without keeping the temperature constant, if the rate of heating or cooling is uniform, so that no kink in the volume-temperature curve arises.

The temperature scale was fixed just above the scale for measuring expansion, and, generally speaking, readings were taken every 4 deg. C.

Remarkably smooth curves were obtained; different specimens of the same steel gave curves which were indistinguishable from each other.

With a direct method such as this, it is clear that the expansions and contractions recorded included the changes of length in the silica tubes; this was found to be less than 10 per cent. of the total length changes and was a constant factor.

Friction of the tubes and specimen in the furnace did not enter into the case, as the pressure involved was very much greater. The diaphragm, being moderately stiff, supplied the spring necessary to follow contractions of the specimen.

A great point in favour of this apparatus is that it is immune from vibrations of both low and high frequency, which are the bane of all methods involving the use of minute moving parts and mirrors.

It might be mentioned that a screen of asbestos card was fixed between the furnace and the micrometer part to prevent the liquid from heating up. The temperature of the dilatometer was kept as constant as possible.

The conclusions reached from a study of the heating and cooling curves obtained were: (1) There is a contraction on the alpha to the gamma change taking place (on heating), this being reversed on cooling in the form of an expansion.

(2) (*a*) Up to a certain carbon content between 0·05 per cent. and 0·6 per cent. the curves show that above the Ac3 point the solid solution assumed a uniform rate of expansion, which does not vary appreciably with the carbon content between these points. (*b*) Above this carbon content, namely, 0·6 per cent., the rate of expansion above Ac3 is increased, up to a temperature depending on the carbon content increasing with this, above which temperature the expansion settles down to a rate similar to that of pure gamma-iron. This was found to be true for all steels tested.

The specimens being used in the tempering tests were hollow, and their uniform thickness being no greater than ⅛ in., it was found possible in every case to obtain a homogeneous product upon quenching.

The electrical resistance of the steels was measured with the apparatus shown in Fig. 2. The furnace con-

* Abstract of paper read before the Iron and Steel Institute, May 14, 1920. The paper contained numerous curves and diagrams which, owing to pressure on our space, we are unable to reproduce.

* Journal of the Iron and Steel Institute, 1919, No. II.

sisted of a silica tube, 2 ft. 6 in. long, wound over 18 in. with nickel-chrome wire and lagged with magnesia, the whole being encased in sheet metal, and the ends of the tube water-cooled. The potential leads and those for the current were made of copper, the former tapping off the potential from two double knife-edges of nickel chrome steel.

The specimens used were all accurately ground and polished to 3 mm. diameter, and a length of 5 mm. between the knife-edges was invariably used.

The resistance of the section of the bar between the knife-edges was measured directly by a Kelvin double-acting bridge, 10 amperes being the steady current sent through the bar.

Readings to the nearest microhm were taken from the bridge, which represented half the absolute values.

The temperature was measured by a platinum-platinum-iridium couple (placed within 1 mm. of the centre of the bar) and a Carpenter-Stansfield potentiometer in conjunction with a galvanometer. The couple was calibrated by the melting points of Sn, Pb, Zn, Al, NaCl, Ag, and Cu, and readings were taken every 6 deg. C., both during heating and cooling.

The thermocouple junction was made by flattening out the ends into thin strips and joining the same. This flat junction was insulated from the bar by a small thin piece of mica, and was protected from direct radiation from the walls of the furnace by asbestos fibre.

For the experiments in the magnetic properties of the steels, the apparatus consisted of a resistance furnace platinum-wound (see Fig. 3), with a primary winding of 5,000 turns on the outside of the magnesia packing. The furnace had a water-jacket between the primary coil and the magnesia, to protect it from the heat, and the secondary coil was a coil of 10 turns of platinum wound between two concentric cylinders of mica, with the adjoining coils insulated by asbestos string. This secondary was made to fit over the specimen (2¼ in. by ¼ in. diameter), and the whole fitted inside the silica tube. The temperature was taken at 6 deg. C. intervals by a platinum-platinum-iridium couple, with the junction placed in a hole drilled in the specimen.

The heating circuit consisted of 140 turns over a length of 40 cm.

The ends of the secondary were joined through a resistance to a ballistic galvanometer, and the throw was measured for a complete reversal of the current in the primary (2·5 amperes, 300 cgs. approximately). The units of magnetisation shown on the curves are the actual throws observed on the galvanometer.

The curves taken were temperature-magnetisation by ballistic method. The normal heating curves differ from those of Honda, &c., in so much that with the field used, namely, 300 cgs., the values found increased slightly up to the critical point, where magnetisation falls to zero, whereas the aforementioned author found the magnetisation values to decrease slightly up to the critical point.

A few temperature-magnetisation curves of annealed specimens were taken, all of which showed no abnormalities except as stated above. Tempering curves of quenched specimens were also taken.

The results of the numerous observations made in this elaborate research have led to the following summary and conclusions: Many of the effects of initial temperature on steels are already known. Besides, such phenomena as excessive grain growth, variations of hardness of the product, &c., in the case of carbon, low nickel, and low chromium steels, there is also the lowering or suppressing of the critical point of nickel, chrome, tungsten, and other steels, when cooled comparatively slowly. That the latter phenomenon also occurs with the aforementioned steels, when the rate of cooling is very much quicker, has been shown by Le Chatelier, Portevin and others.

No direct measurement of any property above the critical range, which might conceivably account for the above-mentioned effects of maximum initial temperature, has been measured till now.

The dilatometer results obtained show that a quantity "carbide expansion" can be measured, which is some indication of the state of the steel at the temperature at which it is measured, and of the behaviour of the steel on cooling.

Thermal resistivity and magnetic data give no obvious indication of this quantity *per se*, but only its effect on subsequent events. Thus while carbide, changing from the normal to the expanded state, has no effect on electric resistance and magnetic properties when in solution in gamma-iron, yet in a martensite, which has been shown to be essentially alpha-iron with expanded carbide, we find the resistance of the alpha-iron considerably increased, and the magnetic permeability lowered by carbide in this state.

That the above effects are not due to gamma-iron in the hardened product has been proved in the resistivity, magnetic and dilatometer experiments, all of which agree in that small quantities of gamma-iron in hardened steels can be measured by changes taking place when tempered above 300 deg. C.

It has been found that a measure of the carbide expansion in steel above the critical range is some indication of how the steel will act on cooling. This assertion is best substantiated by some general notes under the following heading:—

CARBIDE EXPANSION AS A CONTROLLING FACTOR OF THE GAMMA TO ALPHA CHANGE.

In the dilatometer experiments it was found that whenever a steel shows carbide expansion above Ac1,2,3, if on cooling the reverse change did not take place until the normal Ar3,2,1 was reached, the gamma to alpha change was retarded and occurred with recalescence. From the volume change at the normal critical point, it has been shown that the whole of the carbide contraction has completed itself, and the product was found microscopically to be troostite, sorbite, or pearlite, depending on the rate of cooling through this point and the composition of the steel.

Most dilatation cooling curves showed a characteristic dip just above the critical point, indicating that carbide contraction commenced or was accelerated.

In no case did the authors find any sign of carbide expansion persisting in a steel, even a very short time after the gamma to alpha change had taken place at the temperature of the normal transformation. This would be shown in resistivity curves as well as in dilatometer curves if it happened; in the former, by the resistance being above the normal, and in the latter by the volume being greater than the normal. Hence it may be said that carbide in the expanded state (*a*) delays the gamma to alpha change, (*b*) shows signs of its break-up followed immediately by the gamma to alpha change, (*c*) it apparently never survives the normal transformation point, and (*d*) in the case of nickel-chrome steels it has been found that the degree of carbide expansion is associated with the lowering of the critical point down to about 400 deg. C. and then to about 120 deg. C., and finally to below atmospheric temperature.

These observations point to the conclusion that the upper change point (the normal one) cannot be completed unless the carbide expansion has vanished, *i.e.*, that should the carbide expansion persist on cooling, then the upper point (600 deg. C.) will disappear, as in nickel-chrome steels—in fact, it is the persistence of this state in nickel-chrome steels, owing to it being more stable than in carbon steels, &c., which make it and other quaternary steels appear so different.

To the authors only one explanation of the above facts seems feasible, namely, that carbide expansion is a measure of the concentration of molecules of solute, *i.e.*, carbide in the solvent (gamma iron) brought about by dissociation, *i.e.*, breaking down of complex carbide into simpler molecules.

With carbon steels the effect of such mechanism can be seen. Pure iron cannot be kept in the gamma state, however drastically quenched. The allotropic change point is apparently fixed, and the change instantaneous, or at all events controlled simply by the speed at which the heat necessary for the change can be supplied or conducted away, as the case may be.

By adding carbide to give a eutectoid composition in the non-expanded state, *i.e.*, in solution in its most contracted form, giving its lowest concentration of carbide molecules, we lower the change point from 900 deg. to 700 deg. C. on cooling. We may imagine that steel in this form could not be super-cooled to any great extent, its change being controlled by outside factors only.

It has been found, however, that the moment a steel of this composition passes through the critical point of heating, the carbide on passing into solution partially expands, which increases the molecular concentration of the carbide. On cooling from this temperature it is seen from the cooling curve obtained that the steel is contracting at a greater rate than gamma iron, hence the concentration of the carbide is decreasing.

At about 700 deg. C. the remaining carbide contraction takes place simultaneously with the gamma to alpha change. If now we cool quickly from just above Ac1,2,3, then—assuming the carbide contraction change takes time to occur—the concentration of the carbide will keep the iron in the gamma state till it reaches the temperature corresponding to the molecular lowering, when the gamma to alpha change will be completed, leaving the carbide unchanged.

If this occurs below the tempering temperature of expanded carbide, then the result will be martensite, *i.e.*, alpha iron with expanded carbide. This reasoning will hold for nickel and chrome steel of compositions experimented with.

Such a mechanism as this would be in keeping with deductions of Portevin, who states that the upper transformation point gives troostite and pearlite as a product, whereas the lower points give martensite as a distinct intermediate, if not final state. To apply this to nickel-chrome steels we have to consider, as before, that the expanded carbide is more stable than in carbon steels, and differs from it only in the time factor. This would account for the fact that air-cooling of 1 per cent. carbon nickel-chrome steel (3·6 per cent. nickel, 1·7 per cent. chromium) from 950 deg. C. shows a transformation point recorded at about 120 deg. C., which changes about 80 per cent. gamma iron to alpha iron.

On quenching the same steel from the same temperature this transformation cannot be suppressed, and takes place instantly. Hence the factor which prevented this gamma to alpha transformation above 120 deg. C., in the case of slow cooling, is quite powerless to act below this temperature. As no other change of constitution can be detected which would bring about this transformation, everything points to the molecular concentration of carbide being the controlling factor, *i.e.*, carbide expansion.

On considering other steels, particularly nickel steels, it has been found that the stability of expanded carbide is phenomenal for steels of eutectoid compositions. If a greater expansion is obtained by more carbon at high temperatures, then there is a tendency for this to contract on cooling, until eutectoid proportions are reached. Hence the fairly definite point obtained by nickel-chrome steels at 400 deg. and 120 deg. C. might conceivably be so definite, owing to these temperatures corresponding to eutectoids of fixed molecular concentration, and degrees of expansion of carbide, which, being more stable than intermediate concentrations persist longer.

The reversal of the carbide expansion on tempering, *i.e.*, carbide contraction, appears to take place in two stages in the case of high carbon steels, and one stage with lower carbon steel as measured by the dilatometer.

The magnetic data also show the reversal taking place in stages, the resistivity data, however, show a change which is continuous. It is quite conceivable that the deposition of carbide as soon by the microscope in carbon steel tempered at 250 deg. C. may be accompanied by an expansion which apparently splits the carbide contraction into two stages. This change might not show on the resistance curve, thus showing the carbide contraction as a continuous change.

Broadly speaking, then, tempering may be said to consist of (1) change of constitution of carbide in alpha iron, starting at about 100 deg. C. in the case of high-carbon steels, at 280 deg. C. in low-carbon steels, and being completed in both cases at 350 deg. C.; (2) deposition of carbide from 150 deg. C. upwards to 350 deg. C. or so, and (3) the change of any gamma iron at 300 deg. C. upwards. This change is completed within a narrow margin of temperature. It is clear that any carbide in this gamma iron will change its constitution, and be deposited immediately the gamma iron changes to alpha.

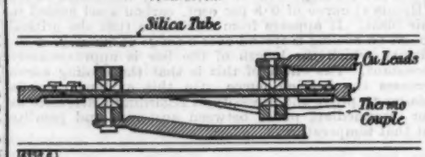
These remarks refer to carbon, chromium and nickel steels, for rates of heating and cooling of the same order as those employed.

For nickel-chrome steels the above holds only in the case of extremely slow rates of heating whilst tempering. In the case of 1·2 per cent. carbon, nickel-chrome steel quenched at 1,300 deg. C., which render it non-magnetic, it has been found that heating at ordinary rates does not sensibly decompose the austenite. A much slower rate, however, does so. For instance, by tempering an austenitic nickel-chrome steel at 600 deg. C., it is possible to produce secondary hardness similar to that in a chrome-tungsten tool steel, the only difference being that, whereas induced secondary hardening in a chrome-tungsten steel is more or less permanent, when produced in a nickel-chrome steel it is of a transient nature.

TABLE I.—SUMMARY OF BEHAVIOUR OF PHYSICAL PROPERTIES.

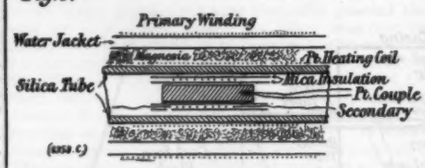
Critical Point.	Thermal.	Dilatation.	Resistivity.	Magnetic.
		1. *Slow Cooling.*		
Ar32	Evolution of heat ..	Increase in volume continuous with Ar1	Fall in resistivity continuous with Ar1	Slight change.
Ar1	Evolution of heat ..	Sudden expansion depending on carbon content and initial temperature	Sudden decrease in resistance	Sudden increase in permeability.
400 deg. C. point in NiCr steels	,, ,, ..	,, ,, ,,	,, ,,	,, ,,
Low point at 150 deg. to 60 deg. C.	Small evolution of heat	Large expansion independent of carbon content	Decrease in resistance ..	Increase in permeability.
		2. *Tempering.*		
Point at 100 deg. C.	No change noted ..	Contraction with carbon greater than 0·6 per cent. when quenched above Ac3,2,1	Decrease in resistance ..	Slight increase in permeability.
150 deg. to 300 deg. C.	Evolution of heat ..	No change	Above change continues..	Above change continues.
300 deg. to 350 deg. C.	Evolution of heat if gamma iron present	Contraction neutralised by gamma iron present	Sudden decrease in resistance if gamma iron present	Sudden increase in permeability if gamma iron present,
500 deg. C. ..	None	None	None	Increase in permeability.

Fig. 2. DIAGRAM OF RESISTIVITY FURNACE



(1358 E)

Fig. 3.



(1358 C)

A nickel-chrome steel containing the usual amount of nickel and chromium and 1·2 per cent. carbon after quenching at 1,000 deg. C. was found to be largely austenitic, and gave a Brinell figure of 205. Upon tempering this steel for 15 minutes at different temperatures, using a separate piece for each tempering experiment, the following Brinell figures were obtained :—

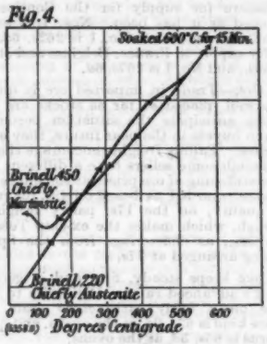
Temperature. Deg. C.	Brinell.
300	212
400	382
500	430
600	592
650	525

It is thus seen that tempering produced a marked increase in hardness, and incidentally a martensitic structure.

Had the change occurred at 600 deg. C., *i.e.*, had it been produced on heating, it would naturally be inferred that the allotropic transformation had occurred at that temperature, since it had been assumed that martensite is alpha iron with carbide in the expanded state. This would, however, be a direct contradiction to the view expressed, that carbide controls the allotropic state, and according to this line of argument complete carbide contraction must precede the allotropic change at that temperature, *i.e.*, 600 deg. C., the resulting product would then not be martensite, but sorbite.

Upon reheating the piece previously heated at 600 deg. C. at a lower temperature, namely, 420 deg. C., for a further 15 minutes, the Brinell figure dropped to 417, showing that the martensitic structure was only a little more permanent than that of carbon steel.

Fig. 4.



The dilatation curve of the tempering shown in Fig. 4 gives the complete solution. Upon heating to a temperature of 480 deg. C. the curve bends towards the temperature axis, *i.e.*, indicating contraction; this continues up to 600 deg. C., at which temperature the specimen was kept constant for 15 minutes.

Had the gamma to alpha change taken place, an obvious expansion would be recorded, whereas at 430 deg. C. and above, a contraction takes place which can only be due to the carbide, *i.e.*, carbide contraction.

Upon cooling, the curve bends towards the heating curve, crossing it at 200 deg. C., indicating that the gamma to alpha change is beginning, whereas at 120 deg. C. this expansion takes place with increased rate, giving rise to the formation of martensite.

Secondary hardening briefly, then, is due to partial carbide contraction taking place above 400 deg. C., which by decreasing the carbide concentration, *i.e.*, molecular concentration, thereby allows the gamma to alpha transformation to take place on cooling below 300 deg. C. It is then, upon cooling, that the increase in hardness was effected, and not at 600 deg. C.

It has never been found possible to suppress this 120 deg. C. point after tempering even by the most drastic quenching, so that under any condition this transformation must occur.

It is not assumed that carbide contraction infers a complete transformation of dissociated into associated carbide, but rather that the carbide in martensite is dissociated to a lesser degree in the alpha iron than it is in the gamma iron of austenite.

If the tempering time is lengthened sufficiently, carbide will contract to allow the change to occur at 400 deg. C., which represents the point on cooling due to the first stage of dissociation, whilst, if the time is prolonged still further, the whole change will take place at 600 deg. C., giving rise to sorbite.

The evolution of a theory, which will agree with, and explain, the principal changes that occur during slow cooling, on quenching and on tempering presents no small difficulty; the authors almost fear to suggest one, so complex do these physical changes appear to be.

Since, however, no work would be complete without even so much as a tentative hypothesis, the authors venture to put forward, what to their minds appears to be the most feasible explanation, in the hope that it will draw forth helpful and instructive criticism.

It is seen in nickel-chrome steels that there are three possible critical points above atmospheric temperature—one at 600 deg. C., one at 400 deg. C., and another at 120 deg. to 50 deg. C. approximately. Points at temperatures intermediate between these never arise, so that the 400 deg. and 150 deg. C. points are not cases of a gradual temperature, *i.e.*, 600 deg. C., the resulting product would then not be martensite, but sorbite.

Upon reheating the piece previously heated at 600 deg. C. at a lower temperature, namely, 420 deg. C., for a further 15 minutes, the Brinell figure dropped to 417, showing that the martensitic structure was only a little more permanent than that of carbon steel.

The dilatation curve of the tempering shown in Fig. 4 gives the complete solution. Upon heating to a temperature of 480 deg. C. the curve bends towards the temperature axis, *i.e.*, indicating contraction; this continues up to 600 deg. C., at which temperature the specimen was kept constant for 15 minutes.

Had the gamma to alpha change taken place, an obvious expansion would be recorded, whereas at 430 deg. C. and above, a contraction takes place which can only be due to the carbide, *i.e.*, carbide contraction.

Upon cooling, the curve bends towards the heating curve, crossing it at 200 deg. C., indicating that the gamma to alpha change is beginning, whereas at 120 deg. C. this expansion takes place with increased rate, giving rise to the formation of martensite.

Secondary hardening briefly, then, is due to partial carbide contraction taking place above 400 deg. C., which by decreasing the carbide concentration, *i.e.*, molecular concentration, thereby allows the gamma to alpha transformation to take place on cooling below 300 deg. C. It is then, upon cooling, that the increase in hardness was effected, and not at 600 deg. C.

It has never been found possible to suppress this 120 deg. C. point after tempering even by the most drastic quenching, so that under any condition this transformation must occur.

It is not assumed that carbide contraction infers a complete transformation of dissociated into associated carbide, but rather that the carbide in martensite is dissociated to a lesser degree in the alpha iron than it is in the gamma iron of austenite.

If the tempering time is lengthened sufficiently, carbide will contract to allow the change to occur at 400 deg. C., which represents the point on cooling due to the first stage of dissociation, whilst, if the time is prolonged still further, the whole change will take place at 600 deg. C., giving rise to sorbite.

The evolution of a theory, which will agree with, and explain, the principal changes that occur during slow cooling, on quenching and on tempering presents no small difficulty; the authors almost fear to suggest one, so complex do these physical changes appear to be.

Since, however, no work would be complete without even so much as a tentative hypothesis, the authors venture to put forward, what to their minds appears to be the most feasible explanation, in the hope that it will draw forth helpful and instructive criticism.

It is seen in nickel-chrome steels that there are three possible critical points above atmospheric temperature—one at 600 deg. C., one at 400 deg. C., and another at 120 deg. to 50 deg. C. approximately. Points at temperatures intermediate between these never arise, so that the 400 deg. and 150 deg. C. points are not cases of a gradual

FIG. 5.—Transformation occurred at 600° C. Normal steel.

FIG. 6.—Transformation depressed to 400° C.

FIG. 7.—Transformation depressed to 150° C.

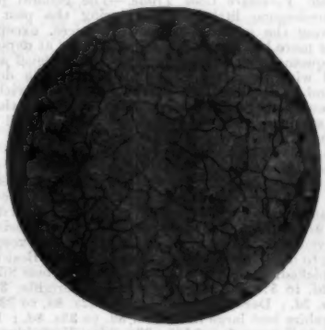


FIG. 8.—Transformation depressed to about 60° C.

FIG. 9.—Chromium Steel, Cr. 1·65 %, C. 1·73 %. Water quenched at 1250° C.

Reduced by one-third. All × 100 diams.

FIGS. 5 TO 9. TYPICAL STRUCTURES OBTAINED WITH NICKEL CHROMIUM STEELS.

depression of the 600 deg. C. change, but represent transformations quite distinct.

French metallurgists regard the 600 deg. C. change as being the transformation from austenite to troostite or sorbite, and the 400 deg. C. point as being due to the formation of martensite, whilst the low point at 120 deg. C. appears to have passed notice.

The evidence for this theory is generally based on microstructure. Indeed, in nickel-chrome steels containing 0·36 per cent. and 0·51 per cent. carbon, whenever the 400 deg. point alone is obtained the structure somewhat resembles that of martensite, and yet the hardness value of these steels thus treated was only 340 and 375 respectively.

In the 0·75 per cent. and 1 per cent. carbon nickel-chrome steels cooled from 1,000 deg. C., giving rise to a point at 150 deg. C., a martensitic structure characterised by an acicular appearance was found.

Honda suggests the presence of two martensites, which he calls "alpha" and "beta."

In the light of these facts, the authors consider the existence of two martensites probable, their basis for the suggestion being as follows :—

1. The retention of the iron in the gamma state is due to carbide concentration.

2. The greater the carbide concentration the greater amount of transformation will occur at the 102 deg. C. point, or below.

3. It is possible to obtain both the 600 deg. and the 400 deg. C. points in the same steel, and likewise the 400 deg. and the 120 deg. C. points together; whereas, if the carbide concentration is further increased no point is observed above atmospheric temperature. The presence of these three points, which occur at fairly definite and constant temperatures, is evidence of three distinct phases in carbide expansion, or, in other words, of three distinct stages of dissociation. The martensite obtained at 400 deg. C. is in all probability carbide in its first stage of dissociation in alpha iron. Martensite obtained after the 120 deg. point is carbide in its second stage of dissociation, whilst pure austenite will be carbide in a sufficiently high degree of dissociation to keep the iron in the gamma state.

This theory is somewhat on the lines of that of Campbell, who, in his numerous papers, appears to suggest this possibility.

The impossibility of obtaining the martensite derived at 400 deg. C., which we will in future call "alpha martensite," in a carbon steel, must be due to the rapid tempering of the same direction after its formation. The martensite obtained, therefore, in a carbon steel being the martensite due to the change at 120 deg. C., which we will call "beta martensite."

A simple dissociation hypothesis such as this, whilst explaining much of the tempering phenomena, fails to explain completely the changes in electrical resistance and magnetic properties that occur upon tempering a quenched specimen.

It is seen from Table I that upon quenching distinct changes may occur, namely, one at 100 deg. to 150 deg. C., shown up by dilatation magnetic and resistivity curves; one at 250 deg. C., shown up by all methods excepting resistivity, and one at 300 deg. C., which may be conclusively put down to the breakdown of austenite where this exists—this is shown up by all methods; and, lastly, a change at 500 deg. C., shown up by magnetic determinations.

If we assume a simple dissociation hypothesis, it does not completely explain the 250 deg. C. change. Taking it for granted for a moment that the simpler theory holds, the change at 120 deg. C. in all probability will represent the association of the carbide molecules, which are then gradually deposited from solution. The maximum rate of this change occurs at 250 deg. C., thus giving rise to the maximum tempering point.

These views do not hold, however, for either magnetic or resistivity curves. Considering for a moment the magnetic properties; when once the carbide has associated, there is no reason why a sudden gain in permeability should arise at 250 deg. C., nor should the annealed steel show a progressive increase in resistance with increase in carbon content if, as has been assumed, Fe_3C has the same resistance as gamma iron.

Magnetic and resistivity tempering curves all point to the fact that some iron is, as it were, locked up by quenching, tending to decrease the permeability and increase the resistance.

Let us consider for a moment what happens precisely on quenching a high carbon steel from 1,000 deg. C. in the light of this possibility. At this temperature it is assumed that we have a true solution, or, in other words, a molecular mixture of dissociated carbide and gamma iron; upon quenching the gamma iron changes into alpha at a temperature of about 100 deg. C. There must be a tendency for the carbide molecules to satisfy their free valency by recombination or association. Since,

however, these molecules, existing as they do, dispersed throughout the mass, whilst the rate of cooling has brought down the molecular mobility of the steel to such a degree as to prevent diffusion and recombination, there will be a tendency on the part of the carbide molecules to combine with the adjacent unsatisfied element, namely, free iron. This gives us then, in a quenched steel, a loose molecular compound of iron and carbide in solution in gamma iron.

This suggested theory agrees well with the experimental data, according to which the decrease in permeability is due to the amount of iron locked up in loose combination. Upon heating above 100 deg. C., the molecular mobility thereby increasing, enables the carbide to gradually associate, thus freeing an increasing amount of iron, and so increasing the permeability of the steel.

Considering the resistivity tempering curves, only one marked point is noted in tempering a pure martensite, namely, at 150 deg. C., due to the aforementioned cause, namely, decomposition of this molecular compound of Fe_3C and Fe. The reason for the occurrence of the low critical points in a nickel-chromium steel, with normal rates of cooling, is the next question to be considered.

The effect of these elements, nickel and chromium, must be that they tend to preserve carbide in the dissociated or expanded state. Three views at least must be considered: (1) The lowering of the points is due to the formation of a double carbide of chromium and iron. (2) Nickel alloying with the iron may thereby effect a relative concentration of chromium, with the result that the lower critical points are due to chromium carbide *per se*. (3) At high temperatures chromium carbide may dissociate, all the carbon eventually combining with the iron, chromium itself going into solution with iron in the same way as nickel, thereby effecting, by its solution as such, a greater stability of dissociated carbide.

This last explanation is the most feasible, in view of the fact that in nickel-chromium steels which have given the 400 deg. C. or 120 deg. C. point alone, upon the carbide being separated electrolytically by Arnold's method this carbide was found upon analysis to contain no chromium.

Typical micros of the various states are shown in Figs. 5 to 9.

FINAL CONCLUSIONS.

1. The effect of variation in initial temperature upon the position of the resulting transformation points in certain nickel, chromium and nickel-chromium steels has been determined.

2. Thermal, dilatation, resistivity and magnetic temperature determinations of all steels experimented with have been carried out.

3. The volume change at the normal transformation points, as shown by the dilatometer, has been found to be composed of two changes working in opposition: (*a*) Allotropic change, and (*b*) change due to carbide. The latter change in steels of high carbon content is not completed at the ferrite or carbide (SE) line, but continues to a temperature depending on its composition, particularly carbon content, increasing with this. This quantity has been shown to be a measure of the molecular concentration of the carbide in solution, and controls the temperature at which the allotropic transformation takes place.

4. Quenching merely stereotypes the condition of the carbide, which, in its turn, controls the allotropic change.

5. This variation in the molecular concentration is readily explained by the assumption that carbide dissociates at and above the temperature of the normal transformation point.

6. Nickel-chromium steels behave in much the same way as carbon steels, excepting that in the latter the time factor necessary to produce the same changes in the carbide is of a much lower order.

7. Martensite has been shown to be the product formed when the allotropic change has been depressed by dissociated carbide, to a temperature at which the latter is able to exist as such in the alpha iron formed. At the temperature of the normal transformation point martensite is not formed as an intermediate phase between austenite and pearlite.

8. When the molecular concentration of the carbide is such that the allotropic change is depressed below atmospheric temperature, the resulting product will be austenite, i.e., the iron is retained in the gamma state.

9. By tempering austenite in such a way that the carbide becomes partially associated, the allotropic change is able to take place on re-cooling, forming martensite, thus explaining the phenomenon of secondary hardening.

10. Electrolytic separation of carbides in a nickel-chrome steel, in which the transformation has not occurred at the normal temperature (600 deg. C.), shows, upon analysis, a total absence of chromium. This is additional evidence that the abnormalities of nickel-chrome steel are due to iron carbide, rendered more stable by nickel and chromium, in solution in the iron.

11. Extensive tempering experiments have been carried out—i.e., dilatation, resistivity, and magnetic—which enable the proportions of alpha and gamma iron in the quenched product of any steel to be determined.

12. It has been shown that in the carbon steels experimented with, quenched at 1,000 deg. C., the iron in the product is in the alpha state. In alloy steels gamma iron is present in various proportions, particularly with high carbon content. In extreme cases alpha is entirely absent.

The authors wish to express their thanks to Messrs. Sir W. G. Armstrong, Whitworth and Co., Limited, and especially to Mr. F. B. Trevelyan, for their kind permission to publish these results, also to Mr. E. F. Law for the interest he has taken in the work.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Iron and Steel.—A rather less confident undertone prevails in the heavy engineering trades. This is attributed to Budget influences, and to the effect of high prices and depreciated foreign currency, the latter principally in relation to business with France, Italy and Belgium. Continental buyers of steel and machinery are more chary about placing orders, except for essential repair work which cannot be longer delayed. Information has been received locally that French buyers are making inquiries in Germany in the hope of obtaining partial relief from that country, but apparently with little success, output there being severely restricted by recurrent labour unrest. But while this state of affairs operates with regard to new business with Continental customers, deliveries of basic materials under contract to all those countries continues on a large scale. Pig-iron, bars, steel rods and angles are the principal requisites. The crucible steel trade is also showing renewed signs of weakness, though this is materially contributed to by shortage of material and fuel. Judging from the sustained activity in other sections of the steel and engineering trades, it is difficult to imagine that the zenith of the trade boom has been reached. Rarely were rolling mills in a more congested state. The volume of orders from commercial automobile makers has increased tremendously, and pressure on output is such that at many of the leading mills substantial arrears have accumulated. This, in turn, is holding up work in the more advanced departments. More plates, sheets, and bright rolled strip are wanted than can be provided at the current rate of output. The manufacture of castings and forgings is a particularly busy branch of local engineering. The construction of large numbers of oil tankers at Barrow is providing Sheffield with a lot of work. This promises to continue for a considerable time ahead, seeing that contracts entered into by one of the largest of South Yorkshire's engineering concerns stipulate for the delivery of a specific number of boats during each of the ensuing six years. Work at the heavy steel foundries is impeded by a scarcity of skilled labour. The extension of electric furnace practice has resulted in the placing of further orders in Sheffield for furnaces of this type. Mild steel is as widely sought for export as at any period during the last six months. All the tool trades and allied branches are well employed. Combines representing the largest engineering concerns are attempting to provide against coming competition by the institution of mass production methods.

South Yorkshire Coal Trade.—The general position has undergone little change during the past week, following the general advance in prices, except that rather more house coal is coming to hand at depots now that quotations are on a more equitable level as compared with those for industrial sorts. The domestic demand is steadier, for which merchants, with large accumulations of arrears on their books, are thankful. Best steam hards are in strong demand by all classes of home consumers. The industrial position locally has improved since a special appeal was made by the Sheffield Corporation to the Coal Controller, though reserve stocks in many cases are very low. Collieries are being strongly pressed for increased supplies of cobbles, nuts and slacks for inland delivery. Cokes of all descriptions are scarce. Furnaces are running at considerable inconvenience. Loss of time is by no means exceptional owing to deficient deliveries. Quotations:—Best branch handpicked, 37*s.* 2*d.* to 38*s.* 2*d.*; Barnsley best Silkstone 37*s.* 2*d.* to 37*s.* 8*d.*; Derbyshire best brights, 35*s.* 2*d.* to 36*s.* 2*d.*; Derbyshire house coal, 32*s.* 8*d.* to 33*s.* 2*d.*; Derbyshire best large nuts, 32*s.* 8*d.* to 33*s.* 8*d.*; Derbyshire small nuts, 31*s.* 8*d.* to 32*s.* 8*d.*; Yorkshire hards, 32*s.* 8*d.* to 33*s.* 8*d.*; Derbyshire hards, 32*s.* 8*d.* to 33*s.* 8*d.*; rough slacks, 28*s.* 2*d.* to 29*s.* 2*d.*; nutty slacks, 27*s.* 2*d.* to 28*s.* 2*d.*; smalls, 23*s.* 2*d.* to 24*s.* 2*d.*

THE INSTITUTION OF MUNICIPAL AND COUNTY ENGINEERS.—The forty-seventh annual general meeting and conference of this Institution is to be held at the Albert Institute, Dundee, on Thursday, Friday and Saturday, June 17, 18 and 19. Further information can be obtained upon application, not later than the 24th inst., to the Secretary, 92, Victoria-street, S.W. 1.

THE INSTITUTE OF METALS.—An invitation from the Mayor and Corporation of Barrow-in-Furness to hold the annual autumn meeting of the Institute of Metals in that town on Wednesday and Thursday, September 15 and 16 next, has been accepted by the Council of the Institute. Particulars of the meeting can be obtained from the Secretary, Mr. G. Shaw Scott, M.Sc., 36, Victoria-street, S.W. 1, who will also be glad to forward tickets for the tenth annual May lecture, which will be delivered by Professor C. A. F. Benedicks, Ph.D., Stockholm, at 8 p.m. on June 10, at the Institution of Mechanical Engineers, Storey's Gate, Westminster, S.W. 1, the subject of the lecture being "The Recent Progress in Thermo-Electricity." The president, Engineer Vice-Admiral Sir George Goodwin, K.C.B., LL.D., will preside. Students of metallurgy, though they may have exceeded the normal age limit of 25, may apply for student membership, provided that their course of studies was interrupted by the war; students if elected may remain in the category of student members up to June 30, 1923, so long as they continue to be students of a recognised school of metallurgy. Members and students are henceforth at liberty to attend the meetings of any of the several local sections throughout the country, without further payment beyond their ordinary subscription to the Institute. Members and students receive cards of admission to, and programmes of, the meetings of the various local sections.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—Notwithstanding last week's advances, the home demand is sufficient to absorb all the Cleveland pig-iron available for sale, and, as producers are adhering to their decision not to sell for shipment abroad, there are no export quotations. Complaint is still made of inadequate distributing facilities. Some slight hope is entertained that the situation may justify the blowing in of one or two blast furnaces in the near future that are ready for lighting. The consequent increased output would be most welcome. The chief obstacle to such a step has been the scarcity of fuel, and now satisfactory supplies of coke are coming forward. No. 1 Cleveland pig-iron finds a ready market at 230*s.* for home purposes, and No. 3 as well as the inferior qualities are promptly taken up at 217*s.* 6*d.*

Hematite Iron.—Scarcity of hematite iron is not so acute as is the case with regard to Cleveland pig-iron, but supply is very inadequate, and makers are not keen sellers. Home requirements are understood to be receiving fairly satisfactory attention, but after such demands have been met, the quantities available for disposal abroad are very limited; a little home and foreign business, however, has been put through this week. Pressure for supply for the Continent is not so pronounced as it has been. Nos. 1, 2 and 3 East Coast brands are 260*s.* and No. 1 is 262*s.* 6*d.* for home use; and for export to France, Belgium and Italy mixed Nos. are 265*s.*, and No. 1 is 267*s.* 6*d.*

Foreign Ore.—Trade in imported ore is quiet. Consumers are well placed so far as stocks are concerned and, as they anticipate the situation becoming more favourable to buyers in the near future, they are holding off the market. Falling freights encourage them in their attitude, though some sellers take a different view, and point to the stiffening of ore prices at the mines. Market quotations are regarded as based on 49*s.* for rubio, of 50 per cent. quality, on the 17*s.* parity freight Bilbao-Middlesbrough, which makes the ex-ship Tees value of best rubio 59*s.*, as charterings from the Spanish ore port are being arranged at 27*s.*

Coke.—Coke keeps steady, firm and in good request at last week's advanced rates. Deliveries to local consumers are on a fairly satisfactory scale. Average blast-furnace kind is 62*s.* 9*d.* at the ovens, and quality low in phosphorus is 65*s.* 3*d.* at the ovens.

Manufactured Iron and Steel.—In the finished iron and steel industries, as manufacturers are heavily in arrears with deliveries and are subjected to ceaseless pressure for supplies, little opportunity indeed is afforded for the transaction of new business. Common iron bars are 26*l.*; steel ship, bridge and tank plates, 23*l.* 10*s.*; steel angles, 23*l.*; steel joists, 23*l.*; soft steel billets, 24*l.*; hard steel billets, 25*l.*; heavy steel rails, 23*l.*; fish plates 28*l.*; black sheets, 40*l.*; and galvanised corrugated sheets, 53*l.* to 55*l.*

Dockers' Strike.—Trade of the river is paralysed by the dockers' strike. Ships are arriving daily and the congestion at the port is alarming. The dispute is over the interpretation of the national award for a minimum payment of 16*s.* per day, the men contending that this means six full days per week, and the employers taking the view that it should mean 11 half-days, as only half a day is worked on Saturdays.

BRITISH WATERWORKS ASSOCIATION (INCORPORATED).—The ninth annual general meeting and conference of this association will be held in the Council Chamber, the Exchange, Nottingham, on Thursday, July 1, at 2.30 p.m. Further particulars can be obtained from the Metropolitan Water Board Offices, South-place, Finsbury, E.C. 2.

THORNYCROFT'S WAR RECORD.—The excellent manner in which our leading engineering firms rose to the occasion during the war is well worthy of record, and it is pleasant to know that many of these concerns are sufficiently proud of their achievements to produce permanent mementoes devoted to them. One of the choicest specimens of its kind is just to hand from Messrs. John I. Thornycroft and Co., Limited, and takes the form of a small quarto volume in which the printed matter is not too prominent and more than half the space is devoted to charming sketches of the firm's works and products. These sketches are reproductions of pencil drawings by Mr. Fred. Taylor, R.I., and afford convincing proof that engineering material in the right hands lends itself exceptionally well to artistic treatment. From the conventional designs of the frontispiece and title page to the tailpiece, there are but one or two sketches which have not lent themselves well to artistic development, and in their case no less than in the remainder the technique lifts them out of the commonplace. Some of the drawings of the shops and yards give a vivid impression of activity, while there is a great deal of life in the drawings of destroyers and motor boats, &c., at sea. Of the larger illustrations the treatment in the sketches of the heavy machine shop, the boiler shop, turbine erecting shop and power station strikes one as more than ordinarily pleasing. The letterpress gives a short history of the firm and an account of the work done in the way of building boats, &c., during the war, with notes on their actions. Bomb throwers for depth charges, motor lorries, launches, &c., are also accounted for. Facsimiles of letters of appreciation from the Lords Commissioners of the Admiralty, add to the interest of the book, which we can only regret has not been accorded some better form of binding.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scotch Steel Trade.—The result of the increased cost of fuel is now being felt all round, and prices have all been adjusted to cover the extra demanded. The Scottish steelmakers' prices have been advanced as from last Wednesday, the 12th inst., and are as follow: Ship plates, ¼ in. and up, 27*l.* per ton; ship plates, under ¼ in. to ⅜ in., 32*l.* 10*s.* per ton; ship plates, under ⅜ in. to ½ in., 34*l.* per ton; angles, &c., 26*l.* 10*s.* per ton; angles and bulb angles under 7 united in., Tees and Zeds under 11 united in., flat bars under 8 in. wide, rounds and squares under 3½ in., and channels under 6 in. by 3 in., 31*l.* per ton, angle basis; and boiler plates, 31*l.* 10*s.* per ton. All the above are basis prices net, and subject to certain extras for delivery. The higher quotations now found necessary cannot have any immediate effect upon the demand for steel material as makers are still very reluctant to enter into fresh engagements on account of their already heavy bookings. There is no easing off in the pressure for deliveries, and consumers have so much work on hand themselves that they are all in very urgent need of supplies. The output is not over satisfactory at the present time, caused largely through difficulty in securing raw material in sufficient quantity, and this is rather a handicap to business. All industries are more or less alike in this matter, but the knowledge of that does not in any manner make for consolation, particularly when there is so much fresh business on offer and which no maker can face. Black sheets are still in great demand, and makers have any amount of orders on hand, and there is also plenty of fresh business on offer. Although prices are very high, the top has not yet been reached, and even to-day's quotations do not keep buyers back, as all are very keen on securing as much as they can lay hands on. With the home trade so busy there is still little signs of any increase in the export of steel. In addition to the foregoing prices the Scotch steelmakers have raised the quotation for rivet bars, which is now 33*l.* 10*s.* per ton, basis net, delivered Glasgow station or equal, with the usual extras.

Malleable Iron Trade.—No change of any kind falls to be recorded in the malleable iron trade of the West of Scotland and with so many works turning out bar-iron it is really remarkable where the large and incessant demand comes from. The pressure for deliveries is maintained and all the works are fully employed.

Scotch Pig-Iron Trade.—The demand for pig-iron is still on a very large scale and the scarcity, particularly of foundry grades, is as great as ever. Now that the price of fuel has caused another increase in quotations it is feared that in some cases there may be a slight easing-off in demand, but this is doubtful considering the large amount required for work under construction. No. 1 foundry iron for the home market is now called 13*l.* 15*s.* to 14*l.* per ton, and No. 3 is from 13*l.* 5*s.* to 13*l.* 10*s.* per ton, free on trucks at makers' works. Export prices are named as 16*l.* 10*s.* per ton for No. 1, and about 16*l.* per ton for No. 3, f.a.s. Glasgow. Hematite is in much request by steelmakers, and producers have raised their quotations by 10*s.* per ton, the price now being 14*l.* 5*s.* per ton, delivered at the steel works. The consumption of this is very large at the present time and the local steel makers are being somewhat hampered in their operations through the shortage of supplies.

CONTRACTS.—Messrs. Waygood-Otis, Limited, Falmouth-road, S.E. 1, have supplied to the Hotel Victoria, Northumberland-avenue, three passenger lifts, each with a speed of 200 ft. to 300 ft. per minute, and with usual control by attendant in the car; two luggage lifts, controlled similarly and arranged for a lift speed of 160 ft. per minute; six service lifts, arranged so that they can be sent or called automatically to or from any floor; an electric lift for general purposes and an hydraulic basement lift.

ELECTRICITY AT THE FIAT WORKS, TURIN.—It is stated that no coal whatsoever is used at these works for driving machinery. For power and light the works consume 15,000 kw. daily, out of a total consumption of 50,000 kw. for the whole of the city of Turin. The desirability, indeed the necessity, of dispensing entirely with coal, was early realised by the Fiat Company, and when the new steel works and forges were laid out they were designed to be operated entirely by electricity secured from water power. The design of the electric furnaces is such that the maximum output is obtained with the minimum consumption of current. Soon after the Fiat Company bought up the Piedmontese steel works and forges, in 1917, the problem was taken in hand of securing sufficient hydraulic power and designing the plant so that no coal would be required. Control was obtained of the Mont Cenis Hydraulic Power Company, which offered remarkable possibilities for obtaining current. The plant existing at that time on the Cenischia River was able to supply 65,000,000 kw., of which 38,000,000 kw. were available in summer and 27,000,000 kw. during the winter months. This amount of current will be considerably increased in the near future, extensive works being now carried out on the Cenischia River. In addition to this, by increasing the size of the natural lake on the Mont Cenis, the current available will be increased to 200,000,000 kw., of which a very large quantity will be available during the winter months. When these extensions have been completed, the whole of the electric current produced by the Mont Cenis Electric Power Company will be reserved for the Fiat motor works at Turin, thus making it the largest, if not the only motor factory in the world in which no coal at all is used for any purpose.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Coal Markets.—As far as the export trade is concerned new business remains very difficult and restricted. In view of the near approach of the Whitsun holidays and the consequent loss in production next week the home demand is of a very pressing character, and as these requirements receive preference, the quantity available for shipment abroad is correspondingly reduced. In fact, only in the case of Italy and the bunkering depots abroad is it possible to secure the release of large coals, and France and other foreign destinations are compelled to take wrought throughs and smalls though occasionally pre-entries are passed for small quantities for washed nuts, beans and peas. Collieries generally are full up with allocations and contract commitments, and buyers find it difficult to secure even small parcels and are compelled to take oddments from different collieries to make up even small cargoes. Prices in the circumstances are very firm, though sellers generally do not show any disposition to force up values. For best large, 115*s.* to 117*s.* 6*d.* is about the figure, and 115*s.* for ordinary large, while throughs range from 105*s.* to 112*s.* 6*d.* and smalls from 92*s.* 6*d.* to 97*s.* 6*d.* Exports, foreign, last week totalled 300,648 tons, or 35,817 tons more than in the preceding week. Of the total, 159,677 tons, equal to 53 per cent., was supplied to France, 49,000 tons to Italy, 3,330 tons to South America, 11,289 tons to Spain, 8,739 tons to Portugal, 63,132 tons to British coaling stations, and 6,481 tons to other countries.

Iron and Steel Trades.—In the tin-plate market business has been brisker during the past week on both home and foreign account. For prompt delivery quotations are round 74*s.* for the basis box and 71*s.* f.o.t. has been done for July-September shipment. Terne plates are in good request and prices are steady at 140*s.* for 28 × 20's o.w. A further quantity of American plates has arrived in this country, and it is reported that there has been much re-selling of Welsh plates bought when prices were much lower. In galvanised sheets there has been little doing, and as makers generally are well sold re-sales by Japan have had no effect on prices which are from 56*l.* up for 24-gauge corrugateds.

Shipping Firm's Big Bonus.—The Globe Shipping Company, Limited, Cardiff, proposes to capitalise a sum of 210,000*l.*, being part of the undivided profits standing to the credit of capital reserve account. The distribution is to take the form of bonus shares, of which 30,000*l.* will pay up the balance of 10*s.* per share now remaining unpaid on the 60,000 issued shares, and 180,000*l.* in payment in full of 180,000 unissued shares of 1*l.* each, in the proportion of three shares for each one share held. The distribution represents a bonus of 700 per cent., and with the 145 per cent. returned in dividends makes a return of 845 per cent. in five years.

PULVERISED COAL FOR POWER STATIONS.—We are informed that the new 40,000-kw. generating station of the Milwaukee Electric Traction and Light Company have decided, after the thorough testing of pulverised coal firing at their existing station, to equip the boilers at the new works with pulverised coal apparatus. The contract for this work has been given the Fuller Engineering Company, who will equip the station with their "Safety First" system; pulverised coal bunkers to carry a reserve of fuel will be erected at the boilers, the powdered coal being mixed with the air for combustion at the actual burners.

AGGLUTINATING-POWER TEST OF COAL.—The agglutinating or caking power of a coal is industrially determined for the purpose of obtaining a measure of the coking value or of the steam-raising value of the coal. The test is performed by mixing and heating the coal, powdered to a more or less fine grain, with a measured proportion of inert material (sand generally), and by weighing the button of coke obtained; the percentage of inert matter that the coal will bear while still yielding a coherent coke is taken as the basis of the coking value. In general a high ash coal is unfit for coking, but such coal may pass the agglutination test well. It is quite understood that the fineness of the grain and of the sand is of importance, and that the presence of ferrous oxide and of some other inorganic constituents, which form fusible slags with the sand, vitiate the test. Anthracite has hence been substituted for sand, but it evolves gas. Recently F. S. Sinnatt, M.Sc., and A. Grounds, B.Sc., have taken electrode carbon (not impregnated) in order to have a material like coal, and yet inert. Before the Manchester Section of the Society of Chemical Industry they described, in February last, researches on the Agglutinating-Power Curve, which they obtain by plotting the mesh of the inert matter against the coefficient of agglutination, i.e., the weight required to destroy the caking power of a unit weight of coal. Experimenting with various Lancashire coals they propose a new way of expressing the caking index, though they quite recognise the difficulty of standardising the test for the present. We do not consider the test suitable for standardisation; there are far too many arbitrary factors, and for practical purposes the coking test of Lessing looks both simpler and of more direct value, and less arbitrary. Some of the points mentioned by Sinnatt and Grounds have a practical interest. They noticed, for instance, that the "dant," the fine by-product of the coal-washing process, reduces the caking value of the coal materially. Finely-divided coke, and the mineral dust sprinkled on the coal for preventing coal-dust explosions, have the same effect, and make coal available for steam raising, for which it would otherwise be unsuitable.

NOTICES OF MEETINGS.

THE ROYAL AERONAUTICAL SOCIETY.—Wednesday, May 26, at 5 p.m., at the Royal Society of Arts, John-street, Adelphi, W.C. Paper on "Some Points of Importance in the Work of the Advisory Committee on Aeronautics," by Sir Richard Glazebrook, Zaharoff Professor of Aeronautics.

THE CONCRETE INSTITUTE.—Thursday, May 27, at 7.30 p.m., at Denison House, 296, Vauxhall Bridge-road, Westminster, S.W. 1. Paper by Major Halsted Best, R.E., F.I.S.E., &c., on "The Mystery Port, Richborough."

THE ROYAL INSTITUTION OF GREAT BRITAIN.—Friday, May 28, at 9 p.m., a discourse will be delivered by Professor W. L. Bragg, M.A. The subject is "Crystal Structure." Afternoon Lectures, at 3 p.m.: Tuesday, May 25, Major C. E. Inglis, O.B.E., M.A., on "The Evolution of Large Bridge Construction" (Lecture I); Thursday, May 27, Mr. William Archer, M.A., on "Dreams—with Special Reference to Psycho-Analysis" (Lecture I); Saturday, May 29, Mr. J. H. Jeans, LL.D., F.R.S., on "Recent Revolutions in Physical Science—(1) The Theory of Relativity."

THE JUNIOR INSTITUTION OF ENGINEERS.—Friday, May 28, at 7.30 p.m., at 39, Victoria-street, S.W. 1. Lecturette "Two Years as an Engineer in the Grand Fleet," by Mr. A. Arnold, Member.

THE INSTITUTION OF MUNICIPAL AND COUNTY ENGINEERS; NORTH-EASTERN DISTRICT.—Saturday, May 29, at 2.30 p.m., Meeting in the Council Chamber, Town Hall, Ilkley. Discussion on paper by Mr. G. A. Waite, A.M.Inst.C.E., on "Notes on Municipal Works of Ilkley" (to be taken as read). Inspect electric wagon and proceed to Waterworks Filter House on Ilkley Moor, near Highfield Hotel; demonstration of washing of Bell's pressure filters. Alternative, if wet—Proceed to council's depot, electric wagon and charging station, fire station, gas and electricity works.

GRAVITATION.—In two papers presented to the Paris Académie des Sciences last October 13 and 27, Q. Majorana suggests that there may be an absorption of gravitation by the medium through which it is propagated. The effect might be similar to magnetic permeability or, more probably, to light absorption. How he understands this absorption of gravitation he does not explain. He deduces, however, that the mass of the sun would be greater than astronomers assume, and that the difference between the true mass and the apparent mass should be of the order of 10^{-12} and should hence be within the limits of experimental verification. The description of his experiments is also quite general. From the beam of a Rupprecht balance (which he places within a strong steel casing so as to be able to work in a vacuum) he suspends two lead spheres, each of 1,274 grammes weight (about 3 lb.), by brass wires; small mirrors are attached to the wires; the one sphere can be lowered into a cylindrical case of wood, 22 cm. in diameter and height, which can be filled with 104 kg. of mercury. The spheres are made to oscillate, the oscillations being watched from outside by means of the mirrors, and these oscillations are counted when the one sphere is, or is not, surrounded by the mercury; a hollow shell round the sphere prevents interference of the mercury with the oscillations. After repeated experiments, Majorana found that the weight of the mass of lead was diminished by 0·0009 milligramme, about the amount expected, when the sphere was surrounded by the mercury. He mentions that his first experiments showed the opposite effect, but he does not explain how he eliminates the various sources of error, some of which are obvious.

THE TANK: ITS BIRTH AND DEVELOPMENT.—The tank, which will stand out as one of the greatest contributions to the war of British mechanical engineering, forms the subject of a very excellently printed book brought out by Messrs. William Foster and Co., Limited, Lincoln, who have the proud claim to being the first firm to bring these machines within the range of practical warfare. The account given in this book of the early work of Messrs. Foster in the way of supplying heavy tractors for large howitzers, and the manner in which this resulted in the demand for a machine capable of bridging gaps is very interesting. The production of Sir William Tritton's tractor fitted with an automatic portable bridge was followed by a trial tank, "Little Willie," the work in the shops being commenced only nine days after the designing had been put in hand in the drawing office, and a trial made just about a month later. The book is a fine record of hard work in designing and mechanical engineering construction. It is greatly to the credit of the firm that appliances so completely novel in character were so expeditiously designed and constructed. It must be a source of immense satisfaction, not only to the principal inventors, but to everyone in the works down to the smallest rivet-boy, that this new weapon proved so successful as a result of the devotion and enterprise of their firm. That tanks now and then came up against conditions which were too much for them is natural, and surprises no engineer. After an examination of some of the pictures in this volume others will also possibly better appreciate this fact also. The wonder is on the whole that they proved so versatile and comparatively long-lived. If any adequate record is ever written of the mechanical engineer's part in the great war, as some day we hope it may—nearly everyone else having had their turn—the production of the tanks will figure honourably among the greater achievements.

THE WORKS OF MESSRS. MARSHALL, SONS AND CO., LTD., GAINSBOROUGH; LEA ROAD POWER STATION.

(*For Description, see Page* 670.)

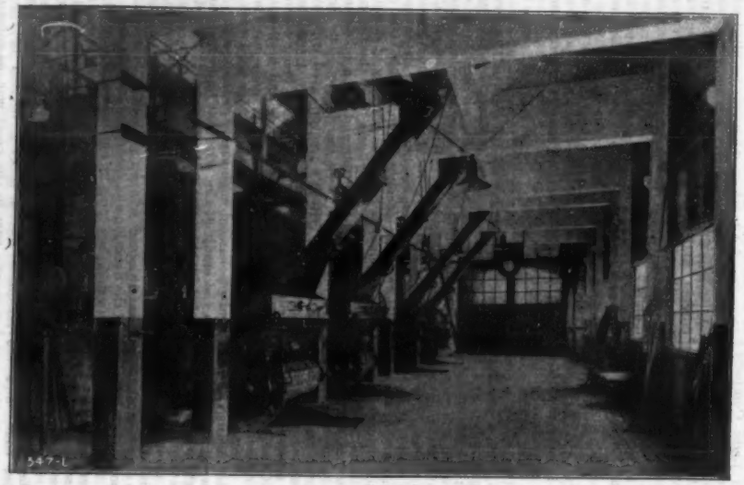


FIG. 41. BOILER HOUSE.

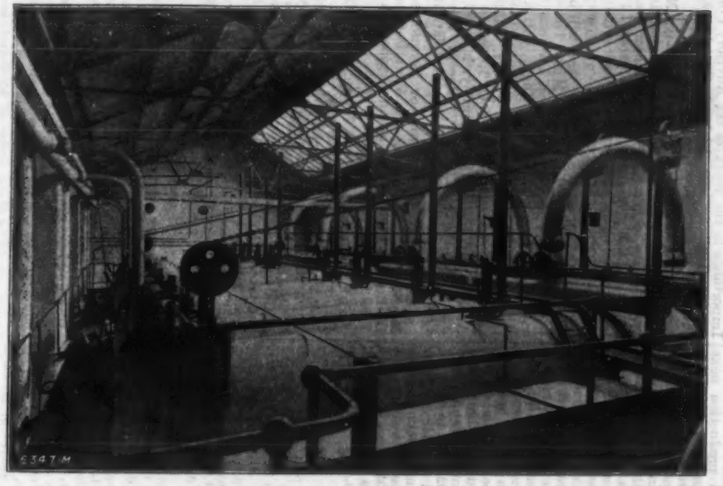


FIG. 42. VIEW OVER BOILERS.

FIG. 43. THE GENERATOR ROOM

FIG. 44. FRONT VIEW OF SWITCHBOARD.

THE WORKS OF MESSRS. MARSHALL, SONS AND CO., LIMITED, GAINSBOROUGH; LEA ROAD POWER STATION.

(For Description, see Page 670.)

Fig. 29.

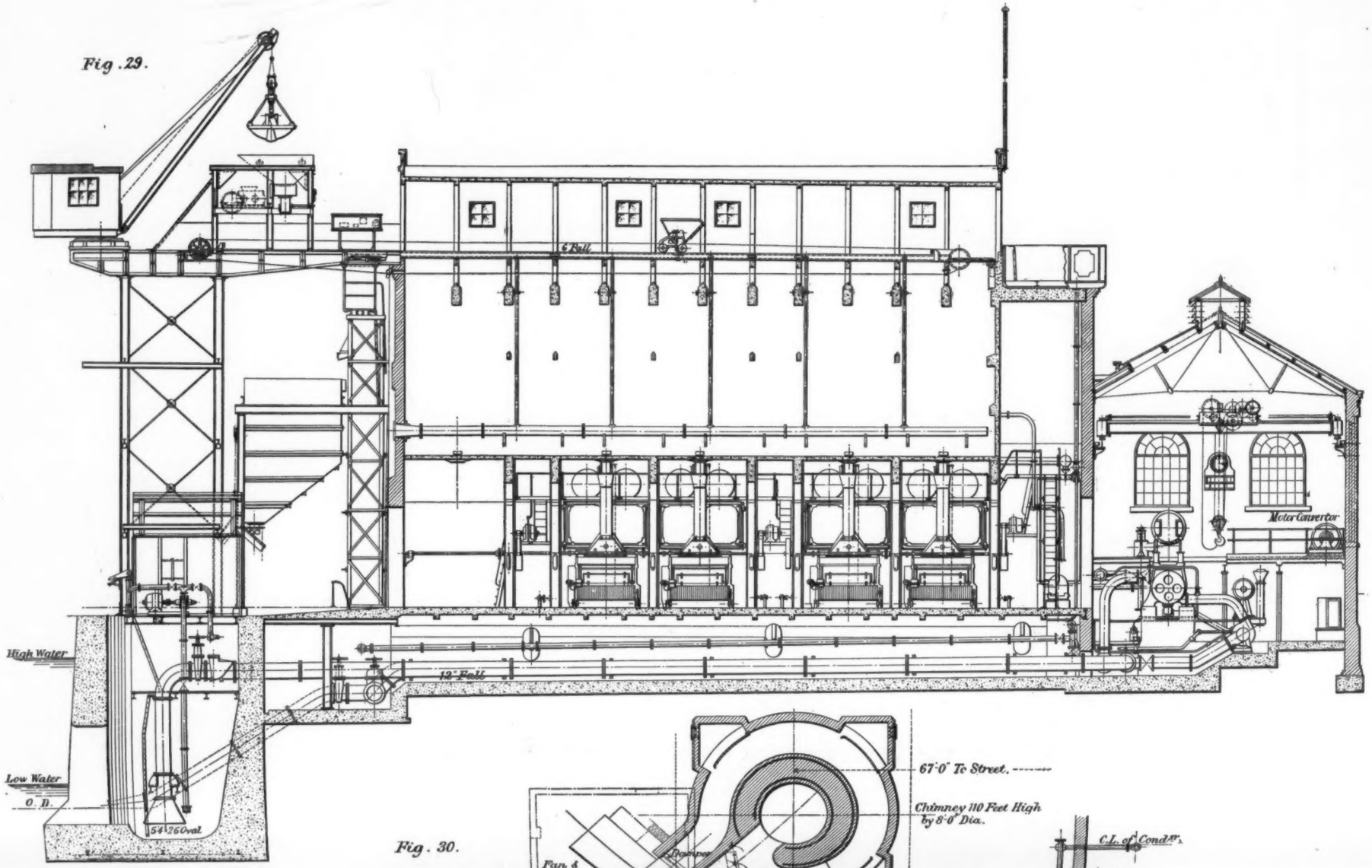


Fig. 30.

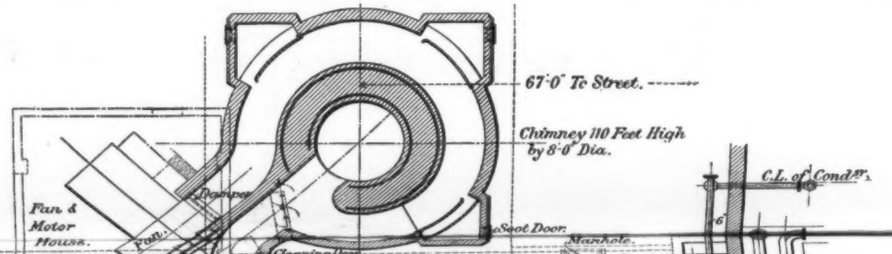


Fig. 31.

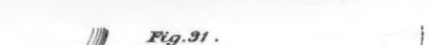


Fig. 30.

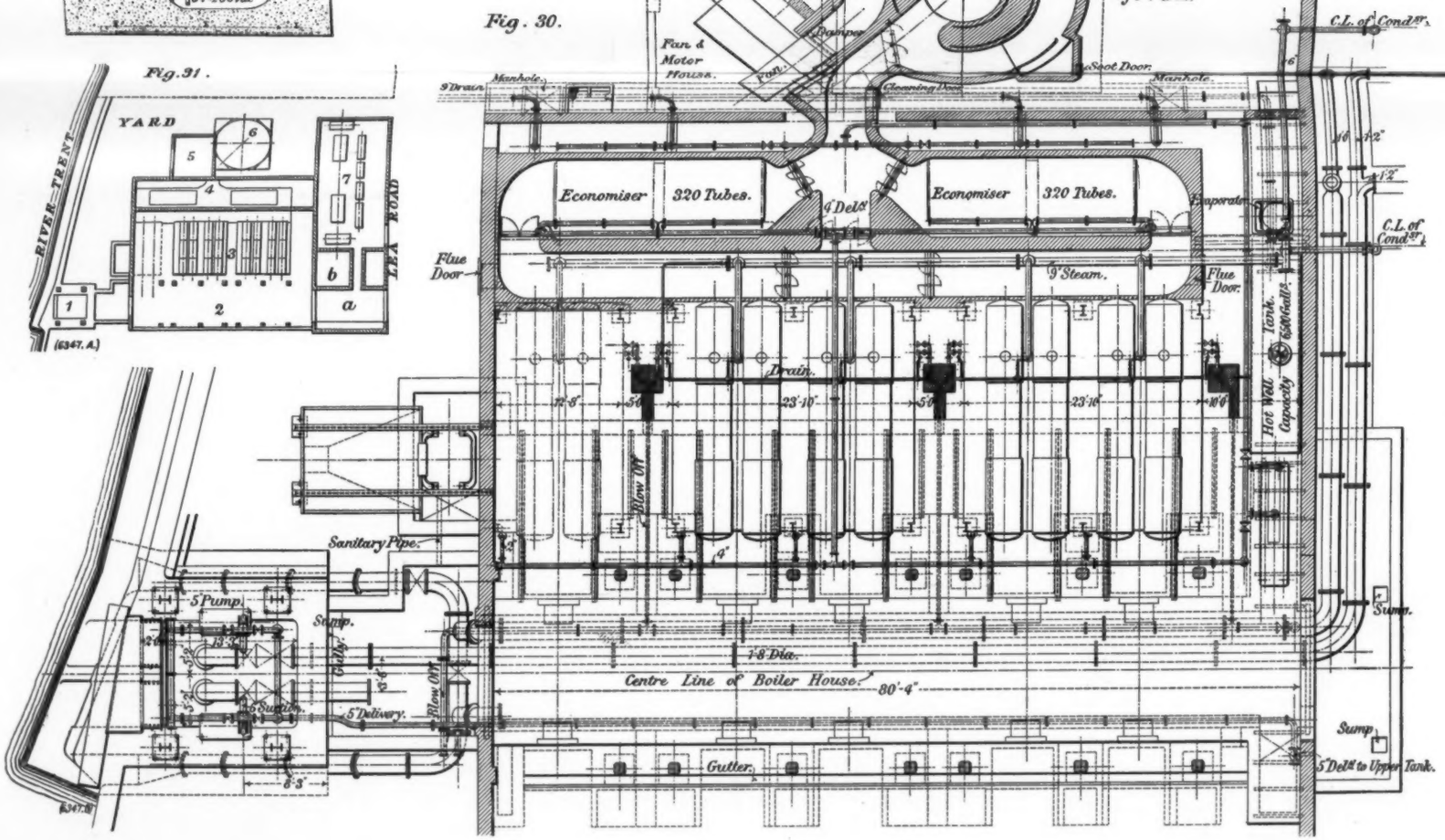


Fig. 31.

Fig. 32.

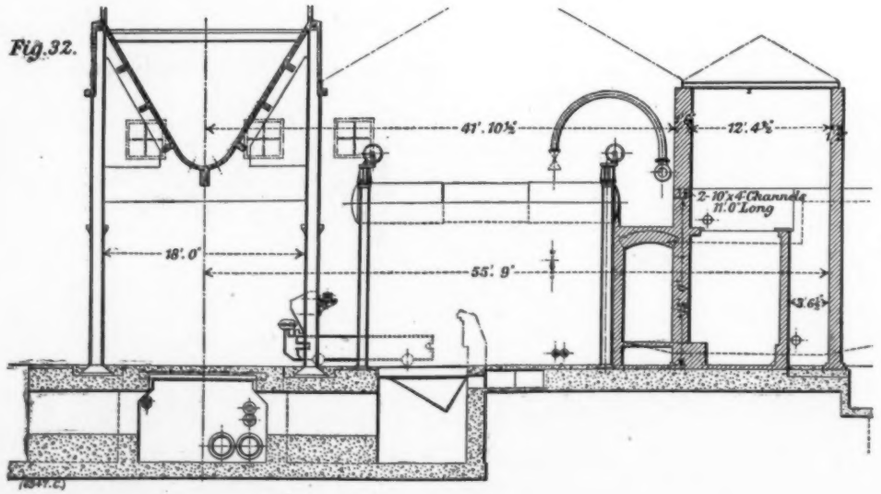


Fig. 33.

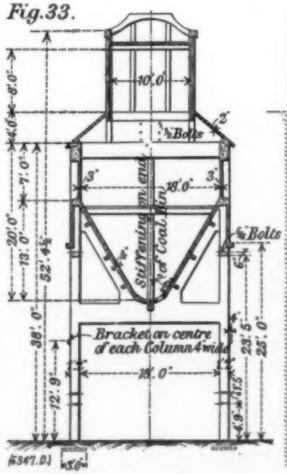
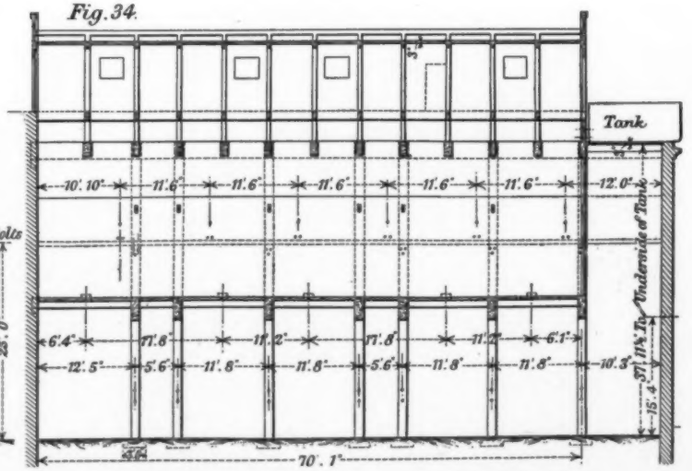


Fig. 34.



AGENTS FOR "ENGINEERING."

AUSTRALIA: Gordon and Gotch, Limited, Melbourne; Sydney; Brisbane; Perth. Angus and Robertson, Limited, Sydney, N.S.W. T. Willmett and Co., Townsville, North Queensland. W. C. Rigby, Adelaide, South Australia. Melville and Mullen, Melbourne, Victoria.
BELGIUM, Brussels: E. F. Satchell, 86, Rue du Tabellion.
CANADA, Toronto, Ont.: Wm. Dawson and Sons, Manning Chambers.
EDINBURGH: John Menzies and Co., 12, Hanover-street.
FRANCE, Paris: Boyveau and Chevillet, 22, Rue de la Banque. For Advertisements, Agence Havas, 8, Place de la Bourse.
GLASGOW: William Love.
INDIA, Calcutta: Thacker, Spink and Co., Bombay: Thacker and Co., Limited.
ITALY: U. Hoepli, Milan. Anonima Libraria Italiana, Torino. And any post office.
LIVERPOOL: Mrs. Taylor, Landing Stages.
MANCHESTER: John Heywood, 143, Deansgate.
NEW ZEALAND: Gordon and Gotch Proprietary, Limited, Wellington, Auckland and Christchurch.
NORWAY, Christiania: Cammermeyer's Boghandel, Carl Johans Gade, 41 and 43.
ROTTERDAM: H. A. Kramer and Son.
SOUTH AFRICA: Central News Agency, Limited, Head Office—Johannesburg; and Pretoria, Cape Town, Port Elizabeth, Bloemfontein, Durban, and their various branches and bookstalls throughout South Africa. Also Cape Town: Wm. Dawson and Sons, 31, Long-street.
TASMANIA: Gordon and Gotch Proprietary, Limited, Launceston: Hobart.
UNITED STATES: For Subscriptions, New York: W. H. Wiley, 432, Fourth Avenue. For Advertisements, J. S. Allan, 18, Broadway, New York.

ADVERTISEMENT RATES.

The charge for advertisements classified under the Headings of Appointments Open, Situations Wanted, Tenders, &c., is four shillings for the first four lines or under, and one shilling per line up to one inch. The line averages seven words. When an advertisement measures an inch or more the charge is 12s. per inch. Payment must accompany all orders for single advertisements, otherwise their insertion cannot be guaranteed. Terms for displayed advertisements on the wrapper and on the inside pages may be obtained on application. The pages are 12 in. deep and 9 in. wide, divisible into four columns of 2¼ in. in width. Serial advertisements will be inserted with all practicable regularity, but absolute regularity cannot be guaranteed.

Advertisements intended for insertion in the current week's issue must be delivered not later than First Post on Thursday. In consequence of the necessity for going to press early with a portion of the edition, alterations for standing advertisements should be received on the Friday previous to the day of publication.

SUBSCRIPTIONS, HOME AND FOREIGN.

REVISED RATES.

"ENGINEERING" may be ordered from any newsagent in town or country and at railway bookstalls, or it can be supplied by the Publisher, post free, at the following rates, for twelve months, payable in advance:—

For the United Kingdom	£3 3 0
For Canada—	
Thin paper copies	£2 18 6
Thick ,, ,,	£3 3 0
For all other places abroad—	
Thin paper copies	£3 3 0
Thick ,, ,,	£3 7 6

When foreign subscriptions are sent by Post Office Orders, advice should be sent to the Publisher.

All accounts are payable to "ENGINEERING," LIMITED. Cheques should be crossed "The National Provincial and Union Bank of England, Limited, Charing Cross Branch." Post-Office Orders should be made payable at Bedford Street, Strand, W.C. 2.

Offices for Publication and Advertisements, 35 and 36, Bedford Street, Strand, London, W.C. 2.

TELEGRAPHIC ADDRESS "ENGINEERING," WESTRAND, LONDON.

TELEPHONE NUMBERS—3663 and 8598 GERRARD.

CONTENTS.

	PAGE
Collision Dynamics (*Illus.*)	669
The Works of Messrs. Marshall, Sons and Co., Limited, Gainsborough (*Illus.*)	670
The Iron and Steel Institute	675
A Simple Drill Chuck (*Illus.*)	678
The Straining of Circulating Water (*Illus.*)	679
Industrial Notes	680
Gear Cutting	680
The Cammell-laird-Fullagar Engine	680
The Effect of Initial Temperature upon the Physical Properties of Steel (*Illus.*)	681
Notes from South Yorkshire	684
Notes from Cleveland and the Northern Counties	684
Notes from the North	685
Notes from the South-West	685
Notices of Meetings	685
Surface Condenser Problems	687
A True Perspective	688
Trade Union Leaders and the Law	689
Commercial Electric Osmosis	689
Notes	690
Literature	690
Books Received	692
Notes on New Books	692
The Properties of Iron-Chromium Carbon Steels (*Illus.*)	692
Royal Meteorological Society	694
The Armstrong Shipyard (*Illus.*)	695
Note on the "Ball Test" (*Illus.*)	698
Encouragement of Invention in Workshop Practice (*Illus.*)	700
A German Industrialist's Views on Socialisation	702
Catalogues	704

With a Two-page Plate of the WORKS OF MESSRS. MARSHALL, SONS AND CO., LIMITED, GAINSBOROUGH; LEA ROAD POWER STATION.

NOTICE.

A few months ago the Proprietors of "ENGINEERING" were compelled to advance the price of this Journal to 1s. per copy, owing to the enormous increases in the cost of paper, engravings and printing, &c. Now higher transport and delivery charges involve a further increase to 1s. 2d. per copy, and this price dated from and included the issue of Friday, April 2, 1920. So long as postal rates remain as at present there will be no increase in the price of copies sent by inland post, which will continue at 1s. 2d. post free.

NOTICE TO NON-SUBSCRIBERS.

In view of the restrictions still imposed by the Government on the importation of paper and the consequent shortage of Supplies, Newsagents will not have copies for chance customers; therefore readers who wish to be sure of obtaining "ENGINEERING" each week should place an order for the Journal with a newsagent or bookstall clerk.

NOTICES OF MEETINGS.

Notices of Meetings to take place during the present and next week will be found on page 685.

ENGINEERING.

FRIDAY, MAY 21, 1920.

SURFACE CONDENSER PROBLEMS.

THE training of the sea-going engineer of fifty years or more ago comprised careful instruction in the precautions necessary to prevent the deposit of salt in the boilers, and he was provided with and used regularly instruments by which the salt content of the boiler water could be determined. He was, moreover, warned that the boilers must be blown down regularly every few hours and filled up again with fresh sea water if serious trouble was to be avoided. The waste of heat in this process was of course obvious, but nevertheless it took many years to introduce the surface condenser into sea service. Marine superintendents have, however, always been highly conservative, and much more inclined to accept the evils they know and can more or less control, than to risk the possibility of unforeseen difficulties arising from the working of apparatus previously untried at sea. For this lack of enterprise they are perhaps hardly to be blamed. Neptune, according to Kipling, exhorted the pioneer navigator to hesitate before he tempted the seas with untested expedients, and warned the adventurer that he must not "make at all, or all make good" his bulwarks and his boasts. A breakdown at sea is still a very serious matter even when, as now, the traffic is pretty dense on most of the ocean highways; and in the middle of last century such a mischance was naturally even more likely to prove disastrous. It is thus perhaps hardly surprising that although the surface condenser was conceived by Watt fully 150 years ago, and actually introduced into service by Hall in 1831, it did not become anything like universal in marine engine practice until several decades later. No doubt the earlier installations were the result of much thought and experiment, but practice soon crystallised, and it was commonly thought, thirty years ago, that we knew about all it was necessary to know as to surface condensers. The surface provided was, in short, fixed by certain empirical rules, a common allowance made being 1½ sq. ft. per I.H.P., whilst in other cases it was made a certain fraction of the boiler heating surface. The introduction of the steam turbine with its capacity of expanding the steam right down to the condenser pressure soon made it evident that these empirical rules no longer provided adequate guidance. New investigations were undertaken and led, mainly by a process of trial and error, to the entire recasting of condenser design. The old marine engine condenser with its baffle plates intended to spread the steam uniformly over the tubes, and the steam lanes which used to be provided through the upper nests, have been discarded as not merely useless but actually prohibitive of efficiency.

Thus in essentials the modern surface condenser is a simpler piece of apparatus than the type it has superseded. Designers have gradually been forced to realise that in the main condenser efficiency was dependent on the reduction to a minimum of the amount of air collected in the casing, and it further became apparent that such an irreducible minimum of air as had perforce to be retained must be prevented from jacketting the tubes. To this end the steamway is contracted systematically as condensation proceeds, so as to maintain to the ultimate end a good rush of steam over the tubes.

Condensers are, however, built for other purposes than for restoring to liquidity the steam exhausted from a steam turbine, and in these condensers, types of design discarded as injurious where a high vacuum is desired, are retained, and in some cases it would seem with considerable advantage.

In a paper* read on Monday evening last, Mr. C. Waldie Cairns and Dr. J. Morrow described a series of experiments on condensers, which they have carried out on behalf of the North-East Coast Institution of Engineers and Shipbuilders. The condensers which were used for the tests were of the type employed for condensing the steam from the auxiliary machinery on shipboard. Here the steam is condensed at atmospheric pressure and is led directly to the boiler-feed pumps. Four types of condenser were tested, of which two of the "contraflo" design were provided with departmental drainage. One condenser was of the common cylindrical type, and the fourth of the pear-shaped pattern now so largely adopted in steam turbine practice. The smallest condenser experimented with had 250 sq. ft. of surface, and was intended to condense 8,750 lb. of steam per hour, whilst the cylindrical condenser, with 600 sq. ft. of cooling surface, was rated only as good for 7,500 lb. of steam per hour. This also was the rated capacity of the pear-shaped condenser, which had 350 sq. ft. of cooling surface. In the tests the actual condensing capacity was fixed by determining the quantity of steam which, with the supply of circulating water available, could be condensed without the temperature of the condensate rising above 180 deg. F., which was considered to be the limit for the supply of the feed pumps under normal conditions of working.

The inferiority of the common circular condenser was made very apparent by the research. Thus this condenser, with its 600 sq. ft. of cooling surface, condensed 11,200 lb. of steam per hour when supplied with 235,000 lb. of circulating water per hour at an inlet temperature of 91 deg. F. The condensate had a temperature of 141 deg. F. The smallest condenser with but 250 sq. ft. of cooling surface condensed 10,000 lb. of steam per hour, the circulating water supply being 148,200 lb. per hour with an inlet temperature of 89·5 deg. F., whilst the condensate temperature was 143 deg. F. In this condenser the lower tubes were drowned in the condensate and the latter was thus cooled before falling into the hot well. This device originated, we believe, with Sir Charles Parsons, being adopted for the condenser supplied with the famous Elberfeld turbine. It is not now generally used for steam turbine condensers, since the provision of special means for the more thorough extraction of air has rendered it unnecessary to take special steps to reduce the temperature of the condensate. It will be seen, however, from the foregoing that the plan seems well worthy of adoption for auxiliary condensers.

In their introductory observations, Messrs. Cairns and Morrow remark that the apparatus at their disposal was such as to make possible merely a comparison of the performances of the four condensers submitted to test, and that they were unable to extend the investigation into one on the laws of heat transfer.

Of recent years a good many experiments directed to this end have been made both here and in America, and the subject has also been investigated theoretically. In no case can it be said that much progress has been achieved. Too many experimenters have failed to note that the resistance to the transfer of heat from steam to circulating water is complex and cannot be expressed by a single term. On the steam side, the resistance is immensely increased by the presence of air. As the steam drifts towards a cold tube it carries with it any air

* Report to the Council of the North-East Coast Institution of Engineers and Shipbuilders on Tests of Auxiliary Condensers, by C. Waldie Cairns, M.Sc., and J. Morrow, M.Sc., D.Eng.

entrained. On reaching the cooling surface the steam disappears as water, but the air remains jacketting the tube and hindering the access of fresh steam. It is this that makes it essential for securing good results at high vacua, to maintain a rush of steam past the tubing so as to sweep away the air which tends to collect there. Apart from this air jacket practically the whole resistance to the heat transfer on the steam side is to be found in the film of water deposited on the condensing surface. This seems to have an average thickness of the order of one mil. and is of course invisible. As it thickens, however, the excess collects up into drops, which can be seen on the surface of the tube if means be provided to this end. The resistance to heat flow through the tube itself is very small, but that on the water side may be very considerable even in the absence of the deposit to which condenser tubes are so liable under certain working conditions.

With suitable provision for the extraction of air the resistance to heat flow on the steam side of the tubes is probably fairly constant, but this is far from being the case with the resistance experienced on the water side even with perfectly clean tubes. Quite commonly experimenters, both here and in America, have measured the total resistance to heat transfer from the steam to the water and endeavoured to find a formula for the heat flow, considering this total resistance as consisting of one term only. Some very curious formulas have been proposed accordingly, but the trouble that has invariably arisen is that each new series of experiments has required a new formula to express the results.

On the theoretical side the pioneer was Osborne Reynolds, but his work was not only incomplete but has been frequently misunderstood and misapplied. Many have thought it possible to deduce from his formula the wall temperature of the tube, but what he really deduced was not this, but a formula giving the temperature of the inside face of the film of liquid which adheres to the walls of the tube and on the average takes no part in the general turbulent flow of the mass of the circulating fluid. Even so, his formula is only applicable to very low rates of heat transfer.

In a paper read some eighteen months ago before the Institution of Engineers and Shipbuilders in Scotland Professor A. W. Porter, F.R.S., attempted to deduce from the theory of dimensions the thickness of the viscous film which slides along the wall of the tube, and the resistance of which constitutes undoubtedly a large fraction of the total resistance to heat transfer. Here again, however, the method employed was valid only if applied to cases in which the rate of heat transfer is extremely small, a condition which was not satisfied in Webster's experiments, the results of which were employed by Dr. Porter to determine the value of his constants.

In fact, in both Reynolds' formula and in that of Dr. Porter there is a term dependent on the viscosity of the water, but this viscosity in condenser practice is very far from being constant across any given section of the tube. Thus the fact that the average temperature, viscosity and velocity of the water is the same in one tube as it is in another of the same diameter is no guarantee whatever that the resistance to heat transfer will be the same in the two cases. In fact, the higher the temperature of the tube the smaller will be the viscosity of the adherent film of fluid, and this film will thus be thinner and offer less resistance, the steeper the temperature gradient along the cooling tube. It would appear, therefore, that any rational formula for the resistance to heat flow on the water side of a condenser tube must include a term dependent on the temperature gradient along the tube and cannot be expressed in terms merely of the average velocity and average viscosity of the water and of the diameter of the tube.

In the meantime engineers have to make condensers and to do the best they can without the aid of a really rational theory of heat transfer. Such a condition of affairs is no novelty, and it is notorious that the steam engine was brought to a high pitch of perfection, with but little guidance save of the most general character from thermodynamic theory, and probably the best present practice in condenser construction would benefit but little by further development of its theory. At the same time a similar feeling to that which makes us take an interest in facts about distant suns like Sirius, or in the details of the ancient civilisations of Egypt and Mesopotamia, impels the engineer to desire fuller reasons for his methods of work than the mere fact that such methods have been successful in the past. Rules of thumb thus provided are often exceedingly convenient, but the designer can never feel certain as to how far he is justified in trusting to them outside of the limits actually covered by experience in the past. This in itself is sufficient reason for the desire to rationalise all engineering formula, and for further experimental and theoretical inquiry into the laws of heat transfer. Such, however, to prove useful must be made with a fuller appreciation of the real nature of the problem than has commonly been the case in the past. A clear distinction must be made between the resistance to flow on the steam and on the water sides of the tubes, and each determined independently and in conditions approximating fairly to those ruling in actual condenser practice.

A TRUE PERSPECTIVE.

IN architecture care has to be taken not to overload a work with detail. There was a time when, forsaking a bold simplicity, craftsmen engaged upon the ornamentation of every feature of a design till the main theme was lost in superimposed ornate intricacies. A reaction followed, and while we may admire the skill shown in the execution of wonderful detail we now appraise at the higher value the design which impresses us favourably as a co-ordinated whole, rather than that suffused with uncorrelated detail. The attention of a painter is first engaged by one part of his canvas and then another, and he works up in succession a number of small points possibly to his entire satisfaction, until, stepping back some few feet to study the effect as a whole, he finds the detail overdone, and the impression he intended to convey by his composition frittered away by a distracting display. He thereupon wipes out his minutiæ to bring once more his theme into the desired prominence, or he may put the canvas on one side and start upon another in the hope of being able to maintain a better perspective and sense of proportion.

A similar situation arises at times with organisations, and this fact was touched upon by Sir Henry Thornton, K.B.E., in his paper on "Some Railway Operating Problems," read before the Institute of Transport on Monday last. Sir Henry Thornton pointed out that in the course of years, first one practice had been introduced into railway working and then another, the adoption of one device was followed by something else, until the complication of added detail became such that changes, instead of being a help, actually tended to become an obstacle to traffic working, and a thorough reorganisation became an absolute necessity. Sir Henry has taken up the position of our painter at some distance from his canvas, and while in touch with every detail of his work is determined that the prominence of any one part must be subordinate to the whole, and that all must work in in his scheme to give the desired effect as a whole which he wishes to put before the public. To this end a very interesting piece of work is being done on the Great Eastern Railway. Metaphorically they have started upon a new canvas. A new ideal train service was drawn up for one section of that railway's suburban system suffering from acute congestion, and with this to go upon, and the co-operation of all the heads of departments interested, by the proper ordering of detail, a service has been devised which is estimated to be an improvement amounting to 40 per cent. on the old.

This improvement is largely the result of saving a few seconds here and there on the road, of cutting down engine requirements at the terminus and making greater provision for these at the out stations. It has involved the addition of pits and extra facilities for coaling and taking water, sometimes with additional staff to assist in these duties. It has resulted in fitting certain trains with automatic train stops, de-railers in docks, additional advance starting, and outer home, signals, with contacts moved closer to the signal, all to secure more rapid working and the saving of seconds. These and other features of the scheme are all matters of everyday consideration, but, as we take it, the great point Sir Henry Thornton was making was that considered piecemeal, as is so often done, individual alterations do not bring much benefit, but when modified in accordance with the requirements of a comprehensive scheme the improvement rendered possible may be immense.

The same necessity for a thorough review of our railways exists in the opinion of Sir H. Thornton in regard to the broader matters of railway policy. Like many others, he approves of consolidation, subject to proper regulation by the State, and he considers that there is still a fertile field for economy in concentrations of management, in standardisation, co-operative purchasing, the elimination of wasteful competitive methods, and in common support and assistance. It is quite true that under our form of Government the public usually gets what it demands—it is up to the railways, therefore, so to educate the public that it learns to demand reasonable things. It is rather remarkable that though the railway people seem to realise that every passenger or trader thinks he could run the railway he uses better than the experts who carry him or his goods from place to place, yet no serious attempt is made to refute many of the absurdities which gain currency through ill-informed sections of the Press. If the licensing or the gas trades, for instance, are attacked, a campaign of aggressive defence is at once developed and in these cases a well-sustained educational policy is also followed. The railways might do worse than copy this example, and certainly would not suffer if they were more forward in keeping the fact in prominence that their prosperity and that of the country are so inextricably interwoven that the latter cannot well be without the former.

As might be expected when the subject is so to the fore the general condition of the *personnel* was also commented upon by Sir Henry Thornton, who attributed a good deal of the restlessness to post-war reaction. He suggests as a contribution to the solution of the present unfortunate *impasse* an organised *personnel* bureau on all large railways administered by an officer of the first rank, with proper temperament, who should make it a duty "to seek out the men's grievances and complaints and bring them immediately to the attention of the proper officer for adjustment." Here, again, we must be careful to look at things in their true perspective. The Pennsylvania Railroad in its recent reorganisation has brought the *personnel* officer into a very prominent position. During the recent war one of the greatest burdens was taken off the technical officers when in certain areas, they were relieved of all duties connected with establishment, camp discipline and so on. Instead of having to spend a good part of their time dealing with matters which did not require specialised knowledge, only giving a meagre balance to the technical side of their work, they were on being relieved of these duties able to concentrate on technical matters and use their knowledge to much greater advantage. This trouble was felt at home in most of the branches of the railway service long before the war. The heads of departments, instead of being able to settle down to the solution of technical problems which they are properly there to tackle, have found their time almost wholly filled with the settlement of labour matters. Relief in this direction would be welcomed by many an engineer. But if it is to be the policy of a special official "to seek out grievances," as was pointed out by a speaker in the discussion, there will very soon be more, either real or imaginary, than it is possible to deal with. The inveterate grouser will be only too pleased to get a ready listener, and we may be sure the normally contented man will not be slow in inventing something as a try-on for the very humour of the thing. Another speaker instanced a case where this had actually occurred, and the situation became so acute that the *personnel* man was got rid of and a new set of superintendents of departments put in with instructions to be sympathetic in their attitude towards the men, with the result that the trouble died out quickly.

It is suggested that the 8-hour day and the larger amount of leisure now on the men's hands has much

to do with the general restlessness. It is not to be doubted that "Satan finds some mischief still for idle hands to do" and perhaps now the men are not sufficiently well occupied. It is said that never before has there been such a demand for clubs, railway institutes, meeting halls, &c. This need should be met wherever possible. Every encouragement should be given to the men to spend their leisure in healthy recreation. Occupied in this way they are much less likely to conjure up imaginary grievances than if they have nothing better to do than lounge about at street corners or in public houses listening, may be, to professional malcontents. Welfare work may carry us some way at least towards the goal of industrial peace.

TRADE UNION LEADERS AND THE LAW.

In a previous issue we referred to the difference of opinion—shown in three recent cases, Valentine *v.* Hyde, Hodges *v.* Webb, and White *v.* Riley and Wood—between Mr. Justice Astbury and Mr. Justice Peterson, as to what constitutes a trade dispute within the meaning of the Trade Disputes Act, 1906. It is apparent from the judgments that these two learned Judges differ also on the broad question of what steps a trade union official may legitimately take in order to procure the dismissal of a worker who refuses to join his union, even assuming that he is acting in furtherance of a trade dispute. In each of the three cases the defendants were officials of a trade union and procured the plaintiff's dismissal from his employment because he did not join the union. In Valentine *v.* Hyde, the officials, without giving any precise intimation, made it clear to the employers that they would cause a strike if the plaintiff were not dismissed; in Hodges *v.* Webb the officials withdrew their members from the job without any threat or warning to the employers; while in the third case, White *v.* Riley and Wood, the employers were notified that the men would strike unless the plaintiff were dismissed.

In each case the Judge had before him the well-known *dictum* of Lord Watson in Allen *v.* Flood:—"There are, in my opinion, two grounds only upon which a person who procures the act of another can be made legally responsible for its consequences. In the first place, he will incur liability if he knowingly and for his own ends induces that other person to commit an actionable wrong. In the second place, when the right induced is within the right of the immediate actor, and is therefore not wrongful so far as he is concerned, it may yet be to the detriment of a third party, and in that case, according to the law laid down by the majority in Lumley *v.* Gye (2. E. and B., 216), the inducer may be held liable if he can be shown to have procured his object by the use of illegal means directed against that third party."

The same question therefore arose in each case, namely, whether the defendants had procured their object by the use of illegal means directed against the plaintiff. In Valentine *v.* Hyde, Mr. Justice Astbury held that the actions of the defendants were of an unlawful character, even if they were acting in furtherance of a trade dispute, and he granted an injunction against them. In White *v.* Riley and Wood, he held that the defendants had conspired to injure the plaintiff by the threat of the strike, that their actions were illegal, and that the plaintiff was entitled to an injunction against them. But in Hodges *v.* Webb, Mr. Justice Peterson held that the defendant's action in actually bringing the men out on strike did not amount to coercion so as to exclude him from the protection of the Trade Disputes Act, and hence the action for an injunction failed.

Allowing for every fine distinction which can be drawn between the facts in the different cases under review, it seems clear that the two learned Judges differ in their views, and the law on the subject will remain unsettled until an authoritative judgment is given by a higher Court. Within the last few weeks the Court of Appeal has decided a case—Davies *v.* Thomas and others—which may be added to the series above discussed without affording much guidance for the future, as the circumstances were somewhat special. The trade union in that case was an association of employers engaged in the supply of yeast. The plaintiff was in the employment of one of the members, a Mr. Williams, as a branch manager, until February, 1919, when he left and entered the employment of another of the members, a Mr. Hopkins, on an agreement terminable on a month's notice on either side. He immediately began to canvass his old customers on behalf of his new employer. One of the rules of the association was as follows:—"20. On an employee leaving an employer who is a member of the association, the employer shall (if so desirous) report the same to the Secretary, who shall advise all the members, and no other member of the association shall employ or supply him for twelve months." The Court held, incidentally, that the rule was void as being an unreasonable restraint of trade. The plaintiff alleged that at a meeting of the association specially convened by the defendants to consider the necessity for members to comply with rule 20, pressure was put on his employer, Mr. Hopkins, which resulted in his giving the plaintiff notice of termination of his engagement. It appears from the judgment of the Master of the Rolls that prior to the meeting Mr. Hopkins had refused to dismiss the plaintiff, but that after a long and animated, if not a heated, discussion at the meeting, and much persuasion, he agreed to do so, but that no threat or coercion was used against him. The same question arose as in the three other cases, viz., had the defendants used any illegal means of procuring the plaintiff's dismissal. It was held that the request to the employer, and the persuasion exercised, did not, in the absence of any threat or coercion, amount to illegal means. This, however, seems to leave open the question whether it is legal for persons to threaten or bring about a strike in order to procure the dismissal of a particular employee.

COMMERCIAL ELECTRIC OSMOSIS.

The term osmosis—from Greek osmos, pushing—had long been familiar to scientists when Graham used it in the 'fifties in connection with his studies of colloids. We do not speak of colloids and crystalloids in the sense of Graham at present. We say that any substance, the metals not excluded, may probably pass into the colloidal condition when sufficiently subdivided by mechanical or other means. The substance is then called a suspension, when the finely-divided "disperse colloid particles" are insoluble in the "disperse medium," or an emulsion, when there is solubility. If the subdivision is complete, giving a homogeneous liquid, we speak of true solution. When the colloidal solution is confined within a membrane, the true solute (crystalloid) passes through the membrane, the colloid proper does not; the separation is ascribed to osmotic forces. In the suspensions the particles generally carry electric charges. Thus silica is electro-positive in water, electro-negative in turpentine, the liquid carrying the opposite charge. The repulsion between the particles of equal polarity is said to maintain the particles separate. The matter is really not so simple, but the particles will coalesce and flocculate if we neutralise the charges. This can be done by immersing electrodes in the solution, when the particles of different polarity, solid or liquid, travel to the respective electrodes of opposite sign. Electrification can also be obtained by adding dissociating electrolytes to the colloidal solution. These are roughly the principles of electric-osmosis, the pioneer of the industrial application of which is the late Count Botho Schwerin. The purification of clay is due to him, and the recent development of his process in this country was demonstrated by Mr. J. Somerville Highfield, Dr. W. R. Ormandy, and Mr. D. Northall-Laurie, in a paper read by them before the Royal Society of Arts on Wednesday last.

Schwerin showed that on adding traces of alkali to a stiff paste of clay and water, the slip became highly mobile, the true clay particles remaining in suspension whilst the impurities, the pyrites, free silica, mica, &c., drop to the bottom of the vessel. The alkali, Mr. Highfield explained, "peptised" the clay particles, by adhering to them and imparting a negative charge to them, owing to which they would, under the influence of an electromotive force, migrate to the anode; the negative clay particle thus remained in suspension, whilst the non-peptised mica, &c., sunk. Similarly acid electrolytes would make the particles travel to the cathode.

Schwerin further showed that particles of different fineness can be separated by electro-osmosis. Mr. Highfield demonstrated this in very simple ways. He had a jar full of a very stiff clay and stirred a teaspoon full of alkali into it; the paste turned fluid like milk. A drop of this milk, falling into a cylinder containing alkaline water spread out in a big cloud, settling very slowly; when a drop fell into acid water, it broke up into a few tiny clouds, which sank rapidly. The purification was more perfect when an electromotive force was applied. When the milky clay was poured into a copper cylinder (cathode) and a metal rod (anode) was inserted, the rod almost immediately became covered with a thick layer of relatively dry clay. This is the basis of the commercial osmotic machine for clay purification, of which Mr. Highfield exhibited a small model yielding 7 lb. of clay per hour. The actual machine is a wooden tank, in the upper part of which a metal cylinder, 2 ft. diameter, 5 ft. long, rests half immersed in the clay suspension; this cylinder is the anode. Its lower half is surrounded by a semi-cylindrical sheet of perforated metal; there is a clearance of ½ in. between the two electrodes. Underneath the cathode are two paddles, turning in opposite directions; they direct a stream of the turbid liquid upward. The clay particles travel to the anode, and the deposited clay is scraped off; the water travels to the cathode, and the effluent water is reused for mixing with fresh clay; the deposit of quartz, mica, &c., is collected and may be utilised.

The fine clay scraped off the anode contains only 25 per cent. of water, Mr. Highfield stated; it was certainly striking to see that, as soon almost as he turned his machine on—the actual anode makes one revolution in 3 minutes—a blanket of white, apparently dry clay was sliding down the scraper. The further drying of this clay was easy, Mr. Highfield explained, and the treatment was sufficiently flexible for ready adaptation to different conditions. The machine mentioned produced about 1,000 tons of pure clay per annum, requiring from 20 units to 70 units of electricity per ton. The very fine photographs of the products obtained, taken by Mr. Laurie in polarised light, made the distinction of the clay, mica, silica particles, &c., very easy.

Another application described was the electro-osmotic filter press for the dehydration and purification of many substances. It consists of filter chambers, the walls of which are formed by perforated or grooved plates of metal or carbon, being alternately anodes and cathodes. In these cells, taking from 20 volts to 100 volts, the water is forced towards the cathode, and such filters certainly promise well for dehydration of colloidal substances which are difficult to dry by centrifugal apparatus and other means.

The successful treatment of metallic slimes, the removal of ash from gelatine, the separation of gelatine from glue, were other problems mentioned by Mr. Highfield. The dewatering of peat, on which Schwerin worked so long, was successful to a certain extent, but the turf was so far obtained in a condition unsuitable for briquetting. As regards the advantage of the clay purification, Sir Herbert Jackson showed one of the osmosed clay crucibles in which he had melted an ordinary clay crucible, and he dwelt upon the importance of the pure clay for the glass-maker and for the industry dealing with refractory materials. Dr. Ormandy mentioned that a muffle made of the osmosed clay of a Cornish firm had stood 15 journeys at 1,500 deg. C., whilst the ordinary muffle of the same firm had only borne three journeys. The industry is only in its infancy in this country, while Austria, Germany and even Spain possess large clay purification works. This is not because the Cornish clay had been undervalued; for Mr. Patchell remarked that Schwerin had, in 1910, prepared an excellent porcelain clay from Cornwall clay sent to him; but in those days there was no demand in this country for the superior product.

NOTES.

THE CONJOINT BOARD OF SCIENTIFIC SOCIETIES.

FOUNDED in 1916, the Conjoint Board of Scientific Societies now represents no less than 57 independent bodies of all kinds connected with science and its application. During the past year four fresh bodies were admitted to membership, and glancing over the long list of participating societies nearly all of importance seem to be included. There are considerable possibilities in the outlook of the Board, but it is evident that if the most is to be made of the endeavour a much larger income will have to be assured. A Finance Committee has this matter now under consideration, and it will be interesting to see, when its report is brought in, how it is proposed to meet the difficulty which unfortunately always seems to hamper these efforts at co-ordination. The Board has 12 committees at work, two new having been created during the year and four discharged. The latter include committees on instruction in technical optics, on education, glues and other adhesives, and on patent laws. The Committee to Prevent Overlapping Among Scientific Societies has worked with a view to encouraging societies to fix the dates and subjects of their meetings earlier so that greater accuracy may be secured in announcements. An endeavour is to be made to group subjects so that country members coming to London may have the advantage of being able to attend two or three meetings of cognate societies within a single week. The effort to arrange for joint buildings is apparently to be persisted in. In the United States something of the kind has met with success, but little headway seems to have been made here. The proposal for a joint library might be encouraged apart from the rest. Many institutions have fairly good individual libraries which would undoubtedly be more valuable and of greater service to the professions if combined. The Board's Committee on Water Power of the Empire has done useful work, having accumulated a great deal of information and assisted Colonial Governments with advice. It is proposed to hold an Imperial Conference on Water Powers in London during the present summer. Attention is drawn to the lack of facilities with regard to specialised training for young men in the field of hydro-electric engineering. A new committee has been set up on war science which, it is hoped, may be capable of doing useful work. We entered the war with our forces poorly equipped in many ways, but with a mass of knowledge available in the country, which, however, was only very slowly organised and put at the disposal of the forces. The war having ended, there seems to be a disposition to allow all this knowledge to be dissipated again, and if the Conjoint Board's effort can do anything towards assuring science of its due standing in our military organisation it will have conferred an enormous benefit upon the nation.

BLAST-FURNACE SLAG BRICKS.

The dearth of coal draws renewed attention to the possibility of obtaining bricks for light buildings from blast-furnace slag without the need of kilns. During the last decades a peculiar kind of white porous building stones of very light weight has become popular on the Rhine; the raw material is the tuffa and pumice-stone of the volcanic Eifel district, but this industry, though not unimportant, is merely local. An industry of blast-furnace slag bricks, which can be manufactured in the ironworks and generally be utilised in the neighbourhood, has likewise developed on the Rhine. In their manufacture the slag is granulated by being dropped into cold water. In the process of Carl Schol, which was worked out at the Oberscheld iron-works, the slag is pushed horizontally into a shallow mass of water so as to be converted, by the steam liberated, into an almost frothy, highly porous material of very low density. Schol calls his material "thermosit." We see from a report on the process by A. Guttmann in *Stahl und Eisen* of March 4, that it is utilised for making both bricks and heat insulators. The density averages 0·3 (from 0·13 upward) while Portland cement has a density of about 2. The thermal conductivity ranges from 0·072 upward, while cork meal has a conductivity of 0·04, and the thermal conductivities of ordinary bricks and of Portland cement are about 0·5 and 0·8. In the manufacture of bricks Schol makes use of presses; the tuffa bricks we mentioned—which are known as Schwemmsteine—are moulded by hand. The thermosit is passed through sieves and the grains of half an inch size and less are mixed with a certain proportion of a binding agent, prepared from fine sand and unslaked lime; the lime is slaked and the dried mixture is ground. One part of this slag-cement and six parts of the thermosit, together with water, are then introduced into a drum from which they enter the brick press, in which pressure is applied first from the top, and then from below. This mode of compression is adopted in order to obtain high porosity and high permeability as well as low thermal conductivity. The bricks leaving the press are very soft and have to be kept for about six hours in exhaust steam before being dried in the open air. In strength the bricks approach the Schwemmsteine, which answer very well in houses of two or three stories, and do not soften under water. The present demand for the Schol bricks is greater than the supply, and the German Government is inquiring into the slag-brick industry with special regard to the housing problem. Not every slag is suitable for thermosit manufacture. The slag should contain about 35 per cent. of silica and not less than 44 per cent. of lime, and Hartmann, manager of the Oberscheld iron-works, referred to several difficulties of the thermosit-brick manufacture. But other blast-furnace slag bricks have long been on the market, and more might and should be done in developing their manufacture.

THE BLUE LIGHT OF THE SKY.

The problem of the blue sky, the ultimate solution of which may, as in other problems, reduce the macrocosm to the microcosm, will remain connected with the name Rayleigh, father and son. When the present Lord Rayleigh, Professor of Physics at South Kensington, discoursed on "The Blue Light of the Sky and the Optical Properties of Air" at the Royal Institution on May 7, he first showed an experiment of his father's. The horizontal beam of the lantern was sent through an acid solution of sodium thiosulphate (the "hypo" of the photographer); sulphur was slowly being liberated, and the fine sulphur particles gave rise to a scattering of bluish light sideways, whilst the disc produced by the transmitted light on a screen in front of the apparatus turned from white into yellow. That bluish light, the late Lord Rayleigh ascribed to the fact that the very small sulphur particles scatter blue light rather than red light, and the blue light of the sky he believed similarly to be caused by the fine dust in the air. But the late Lord Rayleigh calculated that the amount of dust in the air was insufficient to account for the intense blue of the sky, and his son found that when he filtered the air through cotton wool, or when he burned the dust (largely greasy organic matter) in a turbid lantern beam by a Bunsen flame, the streaks of black, optically empty air then produced were still able to cause scattering. It thus appears that the atoms or molecules of gases are themselves capable of scattering light. The scattering is accompanied by polarisation of the light. Turning his Savart polariscope to the neighbourhood of the Polar Star, the lecturer had observed that the faint luminosity of the night sky—which is never quite dark—was far less polarised than daylight, and that observation—confirmed by H. D. Babcock at Mount Wilson Observatory—suggested that the luminosity of the night sky was not due to sunlight but possibly to the Zodiacal Light. Why the blue colour of the sky had been attributed to ozone is difficult to understand. Ozone is blue in transmitted light, but the transmitted beam (in the experiment mentioned) appeared yellow, and if the ozone of our atmosphere were to cause the blue sky, that colour should be most intense when the sun was setting and sending its rays through the deepest layer of our atmosphere. Yet the ozone had much to do with the phenomena. None of the ordinary constituents of our atmosphere, including water vapour, carbon dioxide and argon, stopped ultraviolet rays; but the atmosphere did cut off the ultraviolet end of the solar spectrum, and apparently because it contained ozone. Lord Rayleigh demonstrated this with the aid of the spectrum of the iron arc. Thrown on a screen of cardboard, the spectrum was very short, the ultraviolet region being invisible. When, however, a screen of barium-platinocyanide was used, the whole screen fluoresced brilliantly, until a tube in which oxygen was being converted into ozone was interposed. The intercepted portion of the screen then turned black, but became bright again when the oxygen passing through the tube was no longer ozonised. Now the lines or bands first seen by Huggins in the spectrum of Sirius, had, by Professor A. Fowler and the lecturer, been identified with ozone, the previous identification by Ladenburg being doubtful. Thus ozone appeared to be present in the atmosphere. Watching a mercury vapour arc on a hill in Essex through a horizontal layer of 4 miles of air, however, Lord Rayleigh found the lower atmosphere near the ground far more transparent to ultraviolet radiations than the upper atmosphere, and we had, indeed, little reliable evidence for the presence of ozone in the lower strata. The ozone, disclosed by the observation of Sirius and other stars, would therefore be in the higher strata. The question had more than an academic interest, since that layer somewhere higher up protected our eyes from the fatal effects of the ultraviolet radiations.

LITERATURE.

Hydro Electric Power Stations. By DAVID B. RUSHMORE and ERIC A. LOF. First edition. New York: John Wiley and Sons; London: Chapman and Hall. [Price 28*s.* net.]

IF we premise that the subject of hydro-electric energy, including cognate matters from rainfall to lightning arresters, covers a field much too vast for really comprehensive treatment in a single volume, we may add that the present works forms a most excellent survey of the whole subject. The authors disclaim any intention of writing a treatise on details of design, but have set themselves primarily to discuss the larger and more general problems arising in connection with the construction and operation of hydro-electric plants. Nevertheless, they provide a very large amount of data for design, both numerical and otherwise, weaving it into the substance of the book in such a way that the whole constitutes a most readable and satisfying volume. As might be expected, the examples of hydro-electric development selected for illustration and discussion are exclusively American; yet, since American practice with regard to the utilisation of water power is at least as up-to-date as anything on this side of the Atlantic, this limitation is no particular drawback. North America, including Canada, is believed to have a maximum possible development of 56,000,000 h.p., with a minimum of 31,000,000 h.p., these figures, which exclude storage possibilities, being based on estimates of the United States Geological Survey for the National Conservation Commission of 1908. The extent of hydro-electric development now either completed or in hand in the United States is put at about 6,500,000 h.p., whereas the total primary mechanical power generated in the country for all purposes is estimated at 155,000,000 h.p.

The greater part of the book is concerned with the electrical equipment necessary for generating, transmitting and controlling large quantities of power at high tension, and most of these sections will interest the engineers and designers of steam power plant quite as much as those whose experience is confined to hydro stations. The earlier chapters, relating to matters more exclusively concerning the civil and mechanical engineers, go less into details of construction or calculation, possibly because local conditions at the site naturally cause a far greater diversity of practice with regard to the civil engineering problems than can occur with respect to electrical matters. Nevertheless these chapters embody a lot of useful information which can be generally applied, and the illustration of typical dams and power houses give an excellent idea as to the present state of the art. A third division of the book is devoted to questions of cost, and contains a great deal of unusually detailed data concerning the cost of actual schemes. All the constructional work is itemised and tabulated in an admirable manner, so that the reader knows as clearly as he can be told,

exactly what work each item of expense covers. The information naturally has little bearing on work which might be carried out in other countries, and possibly may not reflect very accurately the conditions which now obtain even in the United States, but this is no fault of the authors, who did all that they could towards furnishing a guide as to costs of construction.

Turning back, and dealing with the chapters in order, the first summarises the history of hydro-electric development in a few pages and gives a chronological table of every important step in the art from the invention of Barkers Mill in 1740 to the inauguration of the 150,000-volt system of the Pacific Light and Power Company, at Los Angeles, in 1913. The water powers of the world in general, and of the United States in particular, are considered, together with the consumption of power in various industrial and metallurgical processes. Rainfall and the gauging of streams are followed by illustrations of typical developments, together with particulars of typical dams and power houses. None of this part goes much into detail, and the same may be said of the chapter on turbines, although here the discussion is somewhat fuller. We now come to the electrical part of the book, which, as we have already said, rather dominates the whole. Generators, transformers, switching arrangements, current-limiting reactors, over-voltage protection, voltage regulation, &c., are all discussed in an admirable manner. The treatment is simple without being elementary, technical without being academic, and practical without being crude. The choice of the subject matter and the method of its presentation leave nothing to be desired.

The class of reader to whom the book will specially appeal, is, we should imagine, the man who is concerned with the design and lay-out of extra-high tension switch gear and current-controlling apparatus. But hardly any engineer connected with the design or operation of large electrical plants can fail to find much that will interest him. Although the range of the work is wide, the hand of the professional book compiler is conspicuously absent. The choice of apparatus for illustration and description, shows no tendency to exalt the practice of any particular manufacturers, in fact, the book is wonderfully free from any suspicion of advertisement. It is, in short, an excellent book, and can be thoroughly recommended. Appendices give a bibliography of, apparently, every hydro-electric development in North America, tabulated data concerning all transmission systems of 70,000 volts and over, and a standard code for testing hydraulic turbines. There is also reproduced in full, in the body of the book, the "General Guide for the Compilation of Water-Power Reports and the Securing of Field Data," published by the Canadian Government as a complete guide to their surveyors when reporting on water powers.

The Flow and Measurement of Air and Gases. By ALEC. B. EASON, M.A., Associate Member of the Institute of Electrical Engineers. London: Chas. Griffin and Co. 1919. [Price 25*s.* net.]

THE increasing use of pneumatic transmission, of ventilating apparatus, the introduction of compressed air systems and of other processes in which moving gases are utilised, have raised many problems that could not be satisfactorily solved without experiments on the flow and friction of gases under varying conditions of temperature, pressure, and volume. The constants deduced from these experiments differ in accuracy, and the formulæ in which they are incorporated are subject to error whose limits cannot be precisely determined. A large literature has centred round this subject, to which these columns have from time to time made original contributions. The sifting and examination of this scattered material, the co-ordination of the results and the discussion of the discrepancies to be found in the conclusions of the different experimenters called for the exact and methodical inquiry which Mr. Eason has undertaken. The book is not easy reading; it is intended for the expert engineer, who wishes to know the degree of reliance that can be placed upon accepted formulæ, and is not deterred in his examination by the exhibition of pages of mathematical deduction. Such an one will be grateful to the author for the sedulous care with which he has collected his material from many sources, and the logical form in which he has marshalled his facts. The author does not suggest the adoption of any constant or formula in preference to others, he presents all impartially, and it is the business of the engineer to draw his own conclusions, assisted as he is in the comparison by the reduction of the material as far as possible to a common standard and unit of measurement. Neither does he aim at minute numerical accuracy, the correctness of the last decimal place does not worry him, because he knows that the nature of the problem will introduce uncertainties very much greater than rough arithmetic can occasion. Of far greater consequence is it to know what constants have been originally used in the formulæ and what confidence is to be placed upon the graphs that appeal so persuasively to the eye.

The first three chapters deal with the flow of gas in pipes and the loss of pressure caused by bends and fittings. The object is to determine a suitable co-efficient of friction (ζ) under the conditions in which air or gas is used for commercial purposes, that is, the conditions in which it may be assumed that the friction varies as the square of the velocity. Even within such restricted limits ζ is not a constant, and generally the problem takes the form of finding ζ for a gas of any density m, flowing at any velocity U, in a pipe of diameter D made of any material, having an internal surface of greater or less smoothness. The examination of many expressions derived by various authorities showed, that the variations in the calculated results from many expressions were dependent upon the value of ζ assumed by the originator of the formula. It was therefore possible to construct charts and to compute tables on an assumed value of ζ (Unwin) and by the use of appropriate factors obtain corresponding values of volumes, quantities and losses of pressure for any other value of ζ that might recommend itself to the reader. This is a valuable simplification and gives a basis for uniformity. An important section in these chapters criticises the formulæ in which the velocity U and the pipe diameter D are affected by fractional indices, and the general conclusion is that the resulting formulæ are to be preferred on the score of accuracy to the older expressions, relying on integers. In another section, it is shown that though the v^2 law is theoretically incorrect, formulæ based upon it are satisfactory for commercial work if an appropriate value of ζ be chosen.

The next four chapters deal mainly with pneumatic tube problems and the strain of pure mathematics is relieved by the occasional introduction of some practical problems, which may be solved by, or, at least, submitted to, scientific treatment. Of such a question as the determination of the most economic size of service pipes in a pneumatic installation. Doubtless existing practice and experience may be regarded as trustworthy guides, but the problem is one that should be re-examined from time to time, because some of the factors entering the problem, as the prices of labour and material, alter considerably and not uniformly, others as the behaviour of air under pressure suffer no change. To obtain the most economical diameter of the pipe, it is to be remembered that the larger the diameter the less will be the loss of pressure and the smaller will be the pressure in the container to produce the required pressure in the apparatus. The cost of installation and the annual charges are increased as the diameter is increased, and to derive a formula in which the two effects balance, and the lowest cost is secured, is not easy, nor is the expression when derived very inviting.

An interesting practical question arises on the proposal to work a system by "looping" two tubes working "up" and "down." It would seem possible, on superficial examination, to effect some economy by looping two parallel tubes, because the kinetic energy of the air flowing out of the "down" tube could be used to augment the energy of the air of the "up" tube. However plausible the suggestion sounds, it is not practical, because the kinetic energy is so small that it can be easily less than the energy required to overcome the friction of the pipes and fittings that would be necessary to loop the tubes. It may be said that there is some increase of speed in the "up" tube, but this is more than counterbalanced by the loss in the "down" tube: provided that the pressure is greater than 6 lb. per square inch. Contrary to expectation, it is found in another problem concerned with the working of tubes, that the effect of a leak in the tube is not so disadvantageous to the practical working as it would seem to be. The existence of a leak can increase the speed and reduce the time of transit. Perhaps it would be more correct to say, that the speed of the first part of the transit is increased, and reduced in the latter, and that the balance may be in favour of the former.

Of greater commercial importance is the discussion of the conditions attending the working of a pneumatic system by the alternative methods of pressure or of vacuum and of the relative advantages attaching to each. With pressures working intermittently the rate of flow is greater than at a continuous rate, and the time occupied by the transit of carriers will be less, but this saving is of little consequence since tubes worked intermittently are always short. In vacuum working, the carrier moves slowly at the beginning of the journey, tending to increase the time of the journey or to diminish the speed. Working with a vacuum of 12 lb. per square inch, the difference of time has been said to amount to 10 per cent., but the author doubts the accuracy of this statement. Some of the observed difference may be due to the methods of manual operation, or possibly the times recorded refer to air transit times and fail to take into account the slip of the air past the carrier. On the other hand, the quantity of air used when despatching intermittently is rather large; no saving is effected in this method, but it is obvious some advantage may arise from being able to work a tube in both directions, and where the traffic is not very great one tube would suffice. In vacuum working the quantity of air used is less, because the mean pressure in the tube is less, and the manipulation of the carriers is somewhat more convenient. The leakage into vacuum tubes is naturally less than the leakage from pressure systems. Some practical tests in London streets showed that pressure tubes worked continuously leaked 4·65 lb. per minute, and vacuum tubes under similar conditions 3·60 lb. per minute. Tubes worked intermittently in both directions gave a leakage of only 1·48 lb. in the same time, but in very old apparatus the leakage amounted to 5·40 lb. per minute. The leakage load varied from 3 per cent. to 5 per cent. of the total air used.

The second portion of the treatise dealing with the measurement of air and gases begins at Chapter VIII, wherein is given a very full description of the principal types of meters in use, with critical comments on the theories underlying their construction. This chapter is marked with the same care and exhaustiveness that distinguish other portions of the book, the remarks on calibration are especially pertinent, but in view of the description of this class of apparatus that appeared in these columns in the spring of last year, no further reference seems necessary. A chapter is devoted to the theory and use of the Pitot tube, and deservedly, for as an instrument for the measurement of air this device has been submitted to a vast amount of experiment and criticism, on the whole the Pitot tube emerges from its rigorous examination with credit. Rowse, of Wisconsin, a few years ago gave an exhaustive report on experiments, determining the constants very accurately. He established the fact that the indications of this instrument, when any abnormal effects due to bends or irregularities in the pipe direction had been carefully eliminated, were correct and reliable to within 1 per cent. The author, after examining the experiments and deductions of a vast number of authorities, appears generally willing to accept Rowse's conclusions, tabulating the results very concisely, though he refrains here as elsewhere from giving any lead in the choice among rival experimenters.

The comparatively novel method of measurement by electric velocity meters and hot wire anemometry is treated with some fullness. It is too early to predict the future of this form of instrument, the author admits that he has seen no commercial meter of this type, while the writer of this note can

go further and say that he has never seen one at all, but from the description and illustration given it is possible to follow the method of working. Mr. Eason states that the chief use of such a meter is to determine the distribution of velocity in air currents, and the direction of the velocities. Quantities of air cannot be so readily measured, as the ratio of the mean velocity of the air over the area considered to the velocity measured by the meter would have to be known. Where the instrument has been used, calibration seems to have been effected by means of a Pitot tube, consequently in practice the correctness of the absolute indications is limited by that instrument. Unfortunately in treating the theory of the hot wire anemometer many physical constants have to be introduced whose accuracy is subject to greater or less doubt. But though the theory is encumbered by the laws of radiation and convection, the specific heat of gases and metals, the temperature coefficients of electrical resistance and other physical properties and constants, it is possible that the instrument may and will be used in situations that cannot be reached by other meters and methods of measurement. The originality of thought shown in the arrangement will justify its construction.

Some miscellaneous problems connected with the air flow from orifices and of air friction on moving surfaces, conclude the mathematical portion of an interesting volume, that testifies to the industry of the author and his skill in summarising a vast amount of original work.

BOOKS RECEIVED.

United States Geological Survey. Preliminary Report on the Mineral Resources of the United States in 1918. No. I: A. *Mineral Production of the United States in* 1916. No. I: 3. *Tin in* 1918. By ADOLPH KNOPF. No. I: 4. *Antimony in* 1918. By HENRY G. FERGUSON. No. I: 21. *Gold and Silver in* 1917 (*General Report*), By H. D. MCCASKEY and J. P. DUNLOP. No. II: 4. *Prices of Coal and Coke*, 1913–18. By C. E. LESHER. No. II: 5. *Salt, Bromine and Calcium Chloride in* 1918. By RALPH W. STONE. No. II: 6. *Fuller's Earth in* 1918. By JEFFERSON MIDDLETON. No. II: 7. *Magnesite in* 1918. By CHARLES G. YALE and RALPH W. STONE. No. II: 8. *Sodium and Sodium Compounds in* 1918. By ROGER C. WELLS. No. II: 9. *Phosphate Rock in* 1918. By RALPH W. STONE. No. II: 10. *Graphite in* 1918. By HENRY G. FERGUSON. No. II: 11. *Slate in* 1918. By G. F. LOUGHLIN and A. T. COONS. No. II: 32. *Coal in* 1917. Part A, *Production*. By C. E. LESHER. No. II: 33. *Natural Gas and Natural-Gas Gasoline in* 1917. By JOHN D. NORTHROP. No. II: 34. *Coke any By-Products in* 1916 *and* 1917. By C. E. LESHER and W. T. THOM, Junr. Bulletin No. 678. *Clay and Shales of Minnesota*. By FRANK F. GROUT. [Price 25 cents.] No. 710. A. *A Reconnaissance of the Pine Creek District, Idaho*. By EDWARD L. JONES, Junr. No. 710. B. *Deposits of Manganese Ore in New Mexico*. By EDWARD L. JONES, Junr. No. 711. B. *Oil Shale in Western Montana, South-Eastern Idaho and Adjacent Parts of Wyoming and Utah*. By D. DALE CONDIT. Water Supply Papers Nos. 429. *Ground Water in the San Jacinto and Temecula Basins, California*. By GERALD A. WARING. [Price 40 cents.] No. 446. *Geology and Ground Waters of the Western Part of San Diego County, California*. By ARTHUR J. ELLIS and CHARLES H. LEE. [Price 1 dol.] No. 457. *Surface Water Supply of the United States*, 1917. Part VII. *Lower Mississippi River Basin*. [Price 10 cents.] No. 485. *Surface Water Supply of Hawaii, June* 1, 1917, *to June* 30, 1918. [Price 15 cents.] Professional Papers No. 113. *Iron-Depositing Bacteria and their Geologic Relations*. By EDMUND CECIL HARDER. [Price 25 cents.] No. 125. A. *An Eocene Flora from Trans-Pecos Texas*. By EDWARD WILBER BERRY. No. 125. B. *Gradations from Continental to Marine Conditions of Deposition in Central Montana during the Eagle and Judith River Epochs*. By C. F. BOWEN. Washington: Government Printing Office.

Atti del Collegio degli Ingegneri Navali e Meccanici in Italia, 1919. Vol. XIV. Genoa: Via Carlo Alberto 18.

Modern Road Construction. By FRANCIS Wood, M.Inst.C.E., F.G.S. Second edition, enlarged. London: Charles Griffin and Co., Limited. [Price 21*s.*]

Calculating Diagrams for Design of Reinforced Concrete Sections. By JAMES WILLIAMSON, A.M.I.C.E. London: Constable and Co., Limited. [Price 12*s.* net.]

Paper Making and its Machinery. By T. W. CHALMERS, A.M.I.Mech.E. London: Constable and Co., Limited. [Price 26*s.* net.]

The Propagation of Electric Currents in Telephone and Telegraph Conductors. By J. A. FLEMING, M.A., D.Sc., F.R.S. Third edition, revised and extended. London: Constable and Co., Limited. [Price 21*s.* net.]

The South and East African Year Book and Guide for 1920. Edited annually by A. SAMLER BROWN, F.R.M.S., and G. GORDON BROWN, F.R.G.S. London: Sampson Low, Marston and Co., Limited. [Price 2*s.* 6*d.*]

Lignes Electriques Aériennes. By PHILLIPE GIRARDET. Grenoble: Jules Rey. [Price 6 francs.]

NOTES ON NEW BOOKS.

THOUGH the state of the cement industry of this country must not be judged from the reduction in the number of works in operation, the predictions of about ten years ago of a decreased activity in cement manufacture have not proved unjustified. By 1917 the number of cement works had gone down to 49, and some of these works were only in partial operation. The decrease in numbers was, however, more than counterbalanced by the increased capacity of some of the works, due to the replacement, already beginning before the war, of the old intermittent type of kilns by continuous vertical and continuous horizontal rotary kilns, the latter several hundred feet in length. In the field of cement literature activity has not been wanting. Apart from foreign books, volumes on cement, concrete and bricks were compiled by G. Redgrave, by Cecil H. Desch, in 1911, by A. B. Searle, 1913, and early this year by E. Dancaster. To this list we have to add the "*Cement*" which Mr. Bertram Blount, F.I.C., has contributed to the "Monographs on Industrial Chemistry," with the assistance of Mr. W. H. Woodcock and Mr. Henry J. Gillett [Longmans, Green and Co., 18*s.* net]. Mr. Blount describes and illustrates new mills, kilns, driers, &c., but does not refer to the state of the British cement industry, except in the historical introduction. Nor does he follow the general practice of devoting a special chapter to the setting of cement. His remarks on these important problems are given in the chapters on the Chemistry of Portland Cement and on the Functions of its various Constituents. We agree with his concluding statement that the chemistry of Portland cement—as distinct from its ultimate analysis—is in a state of flux. Yet he might have paid more attention to the recent literature on the subject, the discussion of which by the Faraday Society (to which he does not refer) would have facilitated his task. We should also, in a chapter on by-products of a new book, look for more information on the dust recovery by the Cottrell process and on the potash recovery from this dust. Other useful chapters deal with Raw Materials, Fuel, Manufacture, Power, Works Control, Testing and Methods of Analysis, Action of Sea Water, Uses of Cement. Together with the appendix on foreign specifications, the volume runs into 283 pages of interesting and instructive reading matter.

Within this twentieth century colloids and colloidal chemistry has assumed an importance that is bewildering to the old generation. If the medieval alchemist insisted that *corpora non agunt nisi fluida*, the modern chemist seems to demand colloidal conditions for many reactions and processes. As regards the living organism the importance of colloidal phenomena has long been recognised; the membranes separating colloids from extortions proper are themselves colloidal. When electrochemists began to advocate electrolytic tanning, however, they were not guided by the conviction that leather was really a colloid. When they had grasped that fact, their processes became less crude and more effective. At present dyeing is acknowledged to be largely a colloidal phenomenon; the manufacture of artificial silk and of squirted filaments, pottery making, the setting of cements, the settling of fused metals into a mixture of crystals and cement, the fertility of the soil, the flotation of ores, silting up of estuaries, &c., are all more or less considered to be colloidal in nature or to involve colloidal processes. In any book the engineer and chemist may read of suspensoids and emulsions and the laboratory chemist is expected to study and prepare gels and sols, about which his professor had not taught him anything for the simple reason that they were foreign to himself. Books on colloidal chemistry are no longer rare. But Mr. Emil Hatschek's "*Laboratory Manual of Elementary Colloid Chemistry*" (published by Messrs. J. and A. Churchill at 6*s.* 6*d.*) is indeed the first of its kind, and it would be sure of a welcome even if Mr. Hatschek were not an authority on the subject, and one who, we may be sure, would not recommend methods that he has not himself found to the purpose. The methods of colloidal chemistry are as peculiar as the materials and the nomenclature. But in spite of the wide character of the problems and of their relative popularity, the student and assistant who could provide himself with ample handbooks on how to conduct an analysis, how to weigh and to measure, and how to handle his spectroscope and galvanometer, hunted in vain for some manual giving him advice as to colloidal work. The duodecimo size of the volume of 131 pages is very convenient for a handbook.

A year ago a joint meeting of the Faraday Society and the Röntgen Society discussed the important subject of "The Examination of Materials by X-Rays" in a meeting which occupied both the afternoon and evening of the day. The discussion, on which we commented at length at the time, as well as the excellent exhibition of apparatus designed for the purpose bearing witness to their proficiency, excited unusual interest, and further contributions to the discussion continued to flow in during subsequent months. The publication of the complete account of the discussion was delayed by this circumstance and by other factors. The full reprint of the discussion from the Transactions of the Faraday Society was hence only published nearly a year after the meeting. The title of the volume of 152 pages is "*The Examination of Materials by X-Rays*," to be obtained from the Faraday Society, 10, Essex-street, W.C. 2, price 13*s.* 6*d.*, bound in cloth. The volume can safely be recommended to all who wish to inform themselves about the peculiarities of X-ray tubes, the principles involved in the application of the rays in industrial radiography for the examination of materials, the apparatus and methods to be used, and the results obtained. Sir Robert Hadfield, the President of the Faraday Society, who himself contributed several papers on the study of steel and other metals, and of carbon electrodes, has also added to the volume translations of two German papers on the investigations of metals by means of X-rays and on the principles governing the penetration of metals by the rays. These papers are, of course, a few years old now, and the science and the applications of X-ray study are advancing rapidly. Yet the papers will be found very useful to the engineer who wishes to understand the principles and working of novel apparatus that he has to adopt. From other papers in the same volume he will learn how the X-ray bulb has proved of great value during the war over here and in France in the testing of various materials, metals, wood, aeroplane parts, &c., for flaws which, in many cases, no other methods could reveal. Though we all know of the dangers of X-rays to the operator, the X-ray method is invaluable because, like ordinary photography, it does its work on the intact piece without affecting it in any way, and with good X-ray bulbs the work is as nearly instantaneous now as the ordinary photographic camera, but more expensive, unfortunately, as yet.

THE PROPERTIES OF IRON-CHROMIUM-CARBON STEELS.*

PART I.—THERMAL ANALYSIS.

By Professor C. A. EDWARDS, D.Sc., Manchester University, H. SUTTON, M.Sc., and G. OISHI.

THE object of the paper is to describe the thermal critical points, and more especially the A1 changes, of a number of iron-carbon-chromium alloys, as revealed when the rate of heating or cooling is very slow, and to record the effects of varying known rates of cooling and initial temperatures upon the carbide changes as well as their influence on the hardness of the material. The work may, therefore, be regarded as an extension, to a fairly wide series of alloys, of an investigation which was published by Greenwood, Kikkawa, and one of the present authors on a steel containing 6·15 per cent. of chromium and 0·63 per cent. of carbon.

TABLE I.—*Brinell Hardness Numbers after being Tested to just above Ac*1 *and Slowly Cooled.*

Sample No.	Chromium.	Carbon.	Silicon.	Manganese.	Brinell Hardness Number. Load, 3,000 kg.
	per cent.	per cent.	per cent.	per cent.	
1967	1·03	0·28	0·03	0·28	170
D.B.	1·12	0·56	0·20	0·55	228
No. 1	1·96	0·38	0·05	0·14	140
A.	2·08	0·87	0·18	0·19	228
B.	2·09	1·00	0·17	0·29	236
C.	2·11	1·26	0·18	0·20	255
C.H.	2·10	1·81	0·12	0·37	274
3,124	2·94	0·38	0·08	0·32	150
E.	3·02	1·09	0·27	0·18	233
No. 2	4·02	0·30	0·15	0·18	156
D.	4·19	0·95	0·32	0·10	260
1,836	4·89	0·70	0·34	0·43	261
K230	4·72	0·11	0·14	0·09	128
3,135	4·93	1·46	—	—	272
F.	5·07	1·07	0·19	0·21	230
X.A.	6·15	0·63	0·07	0·17	225
G.	6·16	0·97	0·31	0·15	254
No. 3	6·18	0·37	0·32	0·24	187
797	6·20	0·70	0·14	0·18	252
1,100A. ..	7·05	0·80	0·14	0·22	255
No. 4	8·08	0·43	0·43	0·25	187
H.	8·12	1·02	0·37	0·11	228
798	9·15	0·90	0·18	0·14	254
No. 5	10·39	0·37	0·50	0·19	196
I.	10·42	1·14	0·46	0·08	231
No. 6	12·08	0·38	0·58	0·24	226
3,208, No. 2 ..	12·60	0·28	—	—	215
3,208	15·06	0·21	0·12	—	215
F.S.	18·31	1·98	0·06	0·21	282

The specimens used were cubes of 1 in. side except in a few instances where the quantity of available material would not permit of such large specimens being taken, when pieces of 1-in. by 1-in. by ½-in. were used.

The temperature of the carbide change on heating was found to be virtually constant for each particular steel, even when the rates of heating were widely different,

* Abstract of paper read before the Iron and Steel Institute, May 14, 1920.

but when the heating was very slow there appeared to be a tendency for the transformation to commence at 2 deg. to 3 deg. lower than when the rate was somewhat rapid.

As a check upon the accuracy of the thermal measurements, the change on heating was almost invariably observed as the specimens were being taken to the required temperature preparatory to cooling.

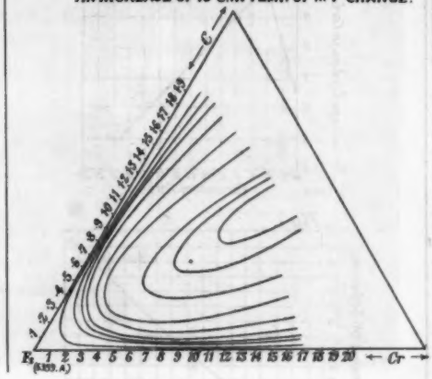
In order to get reliable observations of the temperatures of the carbide change on cooling, samples of each steel were heated to not more than 10 deg. to 20 deg. above their respective Ac1 point, and immediately cooled at a very slow rate. The object of this procedure was to obviate any super-cooling which might occur as a result of accelerated cooling on the one hand, and to prevent a similar effect arising from a high initial tempera-

TABLE II.—*Carbide Change on Heating and Cooling.*

Sample Mark.	Ar1, on Heating.	Ar1, on Cooling.
	deg. C.	deg. C.
1,967	771	737
D.B.	769	728
No. 1	707	743
A.	792	757
B.	790	748
C.	774	745
C.H.	760	730
3,124	805	762
E.	795	757
No. 2	817	764
D.	801	767
1,836	811	769
K220	830	739
3,185	790	752
F.	803	767
X.A.	822	784
G.	825	765
No. 3	833	769
797	824	785
1,100 A.	826	787
No. 4	833	774
H.	829	794
798	833	783
No. 5	835	764
I.	836	800
No. 6	830	762
3,208, No. 2	827	750
3,208	826	750
F.S.	822	738

peratures in a ternary diagram against the corresponding compositions of the alloys. When this is done, as in Fig. 1, and isothermal lines are drawn, the variations in the temperature of the change with composition is very clearly illustrated. Thus it may be stated that, as the chromium is raised whilst the carbon is kept constant, the carbide change occurs at progressively higher temperatures until the carbon to chromium ratio reaches 1 : 10, when a further increase of chromium causes a fall in the temperature of the change. A similar rise occurs with an increase in the percentage of carbon to a series with constant chromium until the ratio is again 1 : 10, after which a further increase of carbon causes a lowering in the temperature of the transformation. Stated in another way, we may say, an increase in the carbon or chromium which has the effect of making the relative quantities of those two elements more nearly approach the above-mentioned ratio produces a rise in the temperature of the change; and the temperature is also raised by increasing the quantity of carbon plus chromium along a line in the ternary diagram corresponding with the

Fig. 1. EACH SUCCESSIVE ISOTHERMAL LINE, FROM THE SIDE OF THE DIAGRAM, CORRESPONDS WITH AN INCREASE OF 10°C. IN TEMP. OF Ar1 CHANGE.



of carbon and chromium in the compound which is deposited, to a line approximating with another compound. This is perhaps more evident when it is remembered what a comparatively small difference there is in the proportion of carbon to chromium contained in some of the compounds which might be deposited from solution. Amongst the more probable compounds which might be the cause of the rise in the temperature of the Ar1 transformation are: $Fe_3C.Cr_3C_2$, Cr_3C_2, $Fe_3C.Cr_4C$, and $2Fe_3C.3Cr_4C$, and their respective carbon to chromium ratios are 1 : 4·3, 1 : 6·5, 1 : 8·06, 1 : 10·44.

By means of magnetic and microscopic examinations, Murakami obtained evidence which he considered indicated the existence of three double carbides having the following compositions, &c.:—

Alpha double carbide	...	$(Fe_3C)_{12}.Cr_4C$
Beta double carbide	...	$(Fe_3C)_8.Cr_4C$
Gamma double carbide	...	$(Fe_3C).Cr_4C$

In a recent paper Ruff and Foehr have made an interesting contribution relating to the constitution of chromium-carbon alloys. They give evidence which appears to place the existence of two definite carbides of chromium beyond dispute. These are Cr_3C_2, which had previously been found by Moissan, and a new one having the formula Cr_7C_3. Their experimental data strongly discredits the view that there is a carbide having the formula Cr_4C.

For the present, therefore, we must conclude that the only binary compounds which are known with any

Fig. 2.

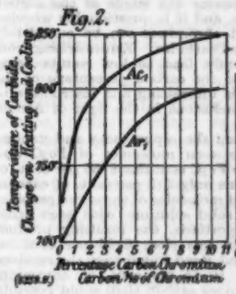
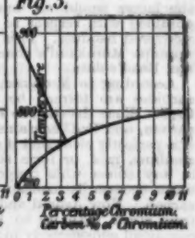


Fig. 3.



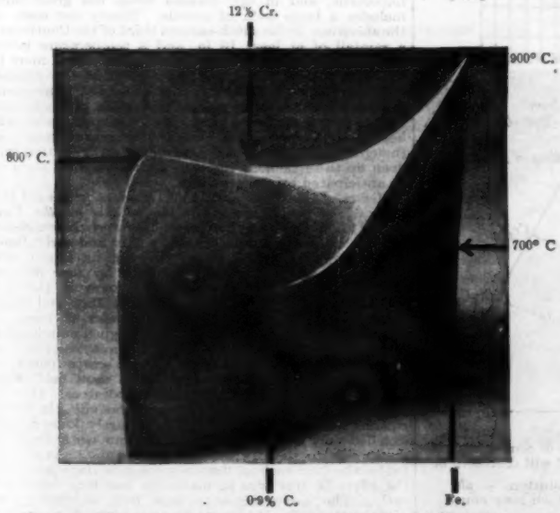


FIG. 4.—Illustrating influence of varying Carbon and Chromium upon the Ar_3 and Ar_2 Points.

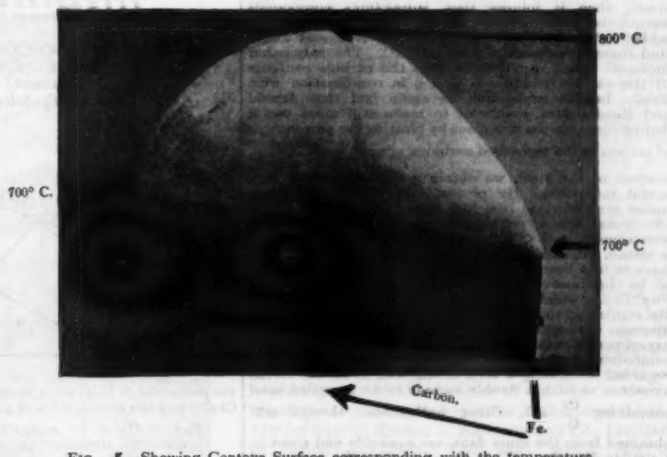


FIG. 5.—Showing Contour Surface corresponding with the temperature of Ar_1 change in Alloys containing varying quantities of Carbon and Chromium.

ture. For some of the alloys this was perhaps an unnecessary precaution, but it was essential with alloys containing high percentages of chromium and low percentages of carbon. With specimens of this kind, both the above variables have a marked influence on the lowering of the temperature at which the carbide separates from solution. By adopting these precautionary measures there was little, if any, indication of recalescence during the period the carbide was being deposited from solution; the change being accompanied by a sudden and prolonged arrest in the cooling of the sample. Having taken these steps to avoid super-cooling, the authors are of the opinion that their results represent the highest possible temperatures at which the carbide change can take place. The Brinell hardnesses of the samples after cooling in this way have been determined, and these are recorded in Table I. The temperatures at which the carbide transformation occurs both on heating and on cooling are given in Table II.

From an examination of the temperatures of the change on cooling, it will be seen that as the percentage of chromium and carbon jointly increase the critical point occurs at higher temperatures. From the tabulated figures alone it is, however, extremely difficult to obtain a clear conception of the exact influence of the composition upon the temperature of the inversion. A much better vision is obtained by plotting these temabove-mentioned ratio. The effect in this connection is very clearly illustrated in Figs. 2 and 3, and also in the solid model, Figs. 4 and 5. These facts lead to the conclusion that the chromium enters into chemical combination with the carbon in these alloys. There is also a strong temptation to carry this further, and conclude that the relative amounts of carbon to chromium in this compound corresponds with the maxima on the carbide surface, namely 1 : 10, but for reasons which will be given later it does not necessarily follow that this is the case. Even if these maxima did indicate the proportion of carbon and chromium contained in the compound which separates from solution at those temperatures, the available thermal evidence would not be sufficient to demonstrate whether it is a binary or ternary compound. One uncertainty in this connection is that these maxima might or might not be discontinued before reaching the binary system, carbon plus chromium. Another point which must not be lost sight of when trying to locate the composition of the compound in question, from a consideration of the thermal data, is the unknown influence of the silicon contained in the samples which have been used in the present investigation. Though the percentages of silicon are not really very high they are certainly not negligible, and might be sufficient to cause the temperature maxima of the carbide change to be displaced from the line corresponding with the proportion

degree of certainty are Fe_3C, Cr_3C_2, Cr_7C_3. On perfectly general grounds it may be taken that these three compounds must be present in some form in certain of the alloys of the ternary system. From theoretical considerations both carbides of chromium, either alone or co-existing, may be present within certain ranges of composition in the ternary mixtures containing high percentages of iron. It is not, however, necessary that this should be so. The system as a whole must subdivide itself into subsidiary ternary systems, and this may take place in a variety of ways according to the relative affinity of iron and chromium for the carbon present, and also of iron and chromium themselves to form solid solutions.

It is somewhat difficult to judge from Murakami's paper whether he considers the alpha and beta carbides to be really definite compounds which are stable in the annealed specimens, or whether they are merely transition products which appear under certain conditions as regards initial temperature and rate of cooling. There is, however, some evidence in the paper that tends to indicate that the so-called beta carbide is in an unstable condition. For example, he found that after isolating this supposed carbide by electro-chemical means, it readily decomposed on being heated to 900 deg. C. Further, even when not isolated it could not be detected in many instances after heating the steels to 900 deg. C., and yet if the same

specimens were heated to higher temperatures the magnetic change-point at 150 deg. C. was found. Therefore, if this magnetic transformation is to be regarded as the deciding test, there would appear to be some reason for supposing that the beta carbide is a transition product which is obtained when certain alloys are heated to high temperatures and subsequently cooled at comparatively quick rates. Turning now to the double carbide $Fe_3C.Cr_4C$, which Murakami considers is present within certain ranges of composition, it will be remembered that this is the compound which, according to the above investigator, separates those steels which show little or no greater facility to harden than carbon steels, from those which possess a considerably greater facility to harden. The evidence upon which Murakami bases his opinion in favour of the existence of this compound, is that obtained from an examination of the microstructures. For the detection of a new compound this method is no doubt very useful, but it certainly does not seem to be entirely satisfactory for determining the composition of a chemical compound, more especially in a complicated system of the kind under consideration. It would prove particularly difficult to do this if an appreciable quantity of the chromium present existed in solid solution with the iron and not in combination as carbide. Fortunately it is possible to obtain information bearing on this question from Arnold and Read's investigation on the separation of the carbides in chromium steels. In this work the carbides were isolated by electro-chemical means. With this method it is almost impossible to recover the whole of the carbon contained in some steels, and it is questionable whether all the excess iron and chromium can be completely removed from the isolated carbides. Errors arising from the latter would no doubt lead to low results being obtained with respect to the carbon percentage of the recovered residues. It is interesting and instructive to examine Murakami's conclusions in the light of Arnold and Read's data.

According to Murakami the alpha, beta and gamma carbides are formed between molecules of Fe_3C and Cr_4C. Since the carbide Fe_3C contains 6·66 per cent. of carbon, and Cr_4C contains only 5·5 per cent. of carbon, it is perfectly clear that if molecules of these two carbides combine, mix, or form solid solutions with each other in any conceivable proportions, the resulting product must necessarily contain less than 6·66 per cent. of carbon. Now Arnold and Read found that the residues from steels with up to 10·15 per cent. of chromium contained considerably more carbon than could possibly be the case if the carbides were such as Murakami supposed. If, therefore, the analyses supplied by Arnold and Read are to be regarded as closely representing the composition of the carbides as they exist in annealed steels, then it follows that Murakami's compounds cannot be regarded as correct. This view receives additional support from the fact that Ruff and Foehr find there is no such carbide as Cr_4C. The only other molecule which would fit in with the carbide contents of the carbide residues is Cr_3C_2, in combination with Fe_3C. In this connection we again find that Arnold and Read's data enable us to make still more useful deductions. In the first place by plotting the percentages of carbon in the recovered carbides against the $\frac{\text{chromium}}{\text{carbon}}$ content of the steel, we obtain a chart affording very useful indication. By plotting the variable, which is under consideration (see Fig. 6), against the carbon to chromium ratio we get an automatical correction for the variations of carbon in the steels. In drawing the lines a certain amount of licence has been taken. The lines have in fact been drawn to correspond to what appears to be the most probable carbide at the peak, namely $Fe_3C.Cr_3C_2$, which would contain 10 per cent. of carbon. By supposing this double compound to be present, the diagram obtained agrees much more closely with the experimental results than would be the case if any other compound were chosen. However, this could not be regarded as making a very strong case in favour of the existence of such a double carbide in an annealed steel containing $\frac{\text{Cr}}{\text{C}}$ 4·3. Other indications, though still obtained from the same data, are available and point in a similar direction. Thus by calculating the amount of chromium required to combine with the carbon in each steel, on the basis that these two elements are present in the carbides in accordance with the analytical results of Arnold and Read, and deducting the figure thus obtained from the total chromium in the steel, the amount of chromium remaining in solution with the iron is obtained. Figures thus computed have been plotted against the $\frac{\text{chromium}}{\text{carbon}}$ in the steel. Neglecting that portion of the diagram which falls to the right of X, Fig. 7, it will be seen that as the carbon to chromium ratio increases from 0·0 to about 4·3 per cent., the amount of chromium which remains in solution is almost zero, but as the ratio increases above 4·3 per cent. the chromium in solution increases to something like 24·7 per cent., when the total chromium ratio is 42. The main point of interest in such a diagram, at this stage, is the very definite break which occurs at 4·3 per cent. This is the ratio which corresponds with the compound $Fe_3C.Cr_3C_2$. The above significant details, along with further evidence that cannot be described in the present paper, lead the authors to conclude that there is a compound formed between the two carbides Fe_3C and Cr_3C_2 which has the formula $Fe_3C.Cr_3C_2$. If this view is accepted we are next confronted with the question of what happens to the chromium when the amount of that element is in excess of the requirements of the above double compound. It has already been shown that some of this additional chromium remains in solution with the iron, even after the carbon has separated on passing through the Ar1 change, but a part of it may go to form a different molecular combination with the carbon. Indeed, Arnold and Read concluded that Cr_4C was a constituent of annealed steels containing high percentages of chromium. The evidence obtained by those investigators was supposed to indicate that Cr_4C was present as a double carbide with Fe_3C as $2Fe_3C.3Cr_4C$. Apart from the fact that the work of Ruff and Foehr throws considerable doubt on the possible existence of Cr_4C, there appears to be good reasons for considering that the double compound $2Fe_3C.3Cr_4C$ does not exist.

For example, if it is agreed that there is a double carbide $Fe_3C.Cr_3C_2$, then the first supplementary ternary system possesses, in the annealed state, the following constitution :

$$Fe_3C + Fe_3C.Cr_3C + Fe \text{ (almost pure)},$$

Under these conditions the alloys must consist of the same double carbide Fe_3C, Cr_3C_2, along with iron containing chromium in solid solution which must be regarded as the same phase as the iron of the first group ; but they cannot possibly contain free cementite. All

Fig. 6.

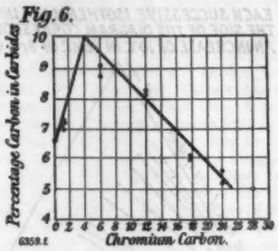


Fig. 7.

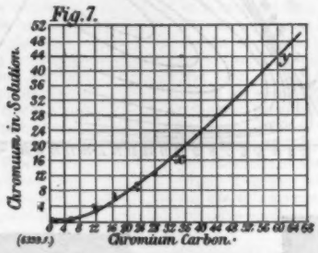
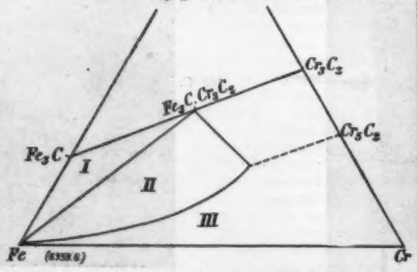


Fig. 8. AREA I.-$Fe_3C+Fe_3C.Cr_3C_2$+Iron
II.-$Fe_3C.Cr_3C_2+Cr_3C_2$+(Iron+Chromium Solution).
III.-Cr_3C_2+Solid Solution of Fe+Cr.



the molecules of Fe_3C must be used up in combining with Cr_3C_2, and the constitution of group 2 will therefore be :

$$Fe_3C.Cr_3C_2 + Fe \text{ with Cr in solution} + \text{an unknown chromium carbide which may contain iron in solid solution.}$$

It seems reasonable to suppose that the unknown chromium carbide in group 2 is the same as that isolated by Ruff and Foehr, namely Cr_3C_2. With this assumption, it may be useful to calculate how much chromium must be present in an annealed steel to cause the whole of the carbon to form the carbide Cr_3C_2. It is doubtful whether this can be done with any degree of accuracy, but it is possible to make an approximate estimate. It is a simple matter to calculate the total amount of chromium it is necessary to have in the alloy, to allow for that which goes into solution and provide sufficient to form Cr_3C_2 for a given carbon content. For 1 per cent. of chromium this works out at 24 per cent. of chromium. It is only by carefully taking into consideration the amount of chromium which goes into solution with the iron, in annealed steels, that anything like a clear conception of their constitution can be gained. Murakami draws a straight line from the point on the chromium-carbon system corresponding with Cr_4C, to the corner representing pure iron, to indicate the alloys in which the carbon is present as Cr_4C. In doing this it seems that a vital fact has been overlooked, namely, a very considerable proportion of the chromium in such alloys is dissolved by the iron. As the result of their studies the authors think the constitution of annealed chromium-iron-carbon alloys may be tentatively represented by the diagram, Fig. 8.

The influence of initial temperature on the critical cooling velocities was also determined for a large number of the specimens. From this point of view the alloys are most conveniently divided into two distinct groups, as was indicated by Murakami. First, those containing more carbon than $\frac{\text{Cr}}{\text{C}}$ = approximately 10, which possess similar hardening characteristics to ordinary carbon steels, and second, those containing more than this ratio of chromium, which have much slower critical cooling velocities. The boundary line dividing these two groups is not very clearly defined, but the irregularities in this respect are considered to be due to the influence of varying quantities of impurities, more especially manganese and silicon. It seems quite impossible to account for this natural subdivision of the alloys without considering that there is a compound corresponding in composition with the line in the ternary diagram, for a carbon to chromium ratio of 1 : 10·0. Without in any way wishing to make a definite conclusion regarding the compound in question, the authors tentatively suggest it is Cr_3C_2.

Whether the increased facility of hardening, which is brought about by heating alloys of the second group to high temperatures, is due to the decomposition of Cr_3C_2 into Cr_3C_2 and chromium, or merely to the presence of an excess of chromium retarding the precipitation of the carbide from solution, it is at present impossible to say. In fact, the true explanation may be found to be something entirely different. Before this problem can be solved much more experimental work will be necessary.

ROYAL METEOROLOGICAL SOCIETY.

THE usual monthly meeting of this society was held on Wednesday, the 19th inst., at the Society's Rooms, 70, Victoria-street, Westminster, Mr. R. H. Hooker, M.A., President, in the chair.

A paper entitled "*Agricultural Climatology of Australia*," by Griffith Taylor, D.Sc., physiographer, Weather Bureau, Melbourne, was read. The author, after indicating briefly the diversity of climates in Australia, pointed out the extreme importance of the rainfall, more so than in most other countries, as the controlling factor in the settlement of the country, also that the season at which rain falls, and the certainty of its occurrence (its "reliability") were as important as the total amount. The greater proportion of the wheat lands lay in regions receiving less than 20 in. of rain per annum, while the crop can be grown with as little as 7 in., if it falls at the right time. Sugar cane is confined to the eastern coast where the rainfall exceeds 40 in., and the temperature 68 deg. F. The hay crop is also important, and in dry seasons when the grain fails, includes a large bulk of cereals. Ninety per cent. of the sheep are in the south-eastern third of the Continent : a rainfall of at least 10 in. and a temperature below 77 deg. is required for them. Cattle are reared more in the north-east. The great variability of the rainfall frequency results in serious droughts and consequent failure of the cereal crops and reduction of flocks and herds ; but it is hoped that these recurrent losses will become less serious in time with the progress of irrigation, though Dr. Taylor is not sanguine that irrigation will open up to settlement the enormous areas that seem to be anticipated by some writers.

Messrs. J. E. Clark and H. B. Adames presented the "*Report on the Phenological Observations for the Year* 1919." The dominant factors in 1919 were the excessive wetness until April and drought in May and early June, lasting or reappearing until October or later ; the abnormally warm December followed by four months universally cold, closing with heavy snow in the last week of April. Then hot summer in May and early June, preceded a detrimental six weeks or more of abnormal cold. Cold recurred after August, culminating in a November deficiency beyond most records. In consequence, summer-growing garden crops (such as celery and cauliflower) were poor, and most field crops short, though fairly good, especially potatoes. Of tree fruits only plums and apples cropped heavily, the latter ripening and colouring to a degree rarely known, and excelled only by the wonderful autumn tints, both no doubt due to the dry and sunny autumn. As to the tables the four earliest flowers were nine days late, but the effect of May was to make the last four decidedly early. The early migrants were late, especially the nightingale. The 1919 isophenes are seven days further south than in 1918. The number of observers have been further reduced from war effects, barely exceeding 100, but 1920 prospects are such that at least 100 per cent. increase is probable. The areas worst represented are Wales, the south-west half of Ireland and north-west of Scotland. Observers from these parts will be most welcome.

RECORD AEROPLANE FLIGHT.—An aeroplane flight which has established a British record for height, duration and useful load was accomplished by a Handley-Page type W.8 machine on the 4th inst., at the Cricklewood Aerodrome. The machine, which was fitted with two Napier "Lion" engines, each of 450 h.p., was piloted by Captain G. T. R. Hill, and it carried a useful load of 1,674 kg. (3,690 lb.) to a height of 6,267 m. (13,999 ft.) in a flight lasting 1 hour 20 minutes. A certificate of performance has been granted by the Royal Aero Club under the regulations of the Fédération Aéronautique Internationale, but no special preparations were made for the flight, the load, which would be equivalent to 26 passengers, being composed of timber, water ballast tanks, and some special instruments. The tanks were placed in the passengers' saloon from which the chairs were removed, but the various fittings and decorations were allowed to remain. It may be interesting to add that the particular machine with which the record was established is the one recently exhibited at the Paris Aircraft Exhibition, to which it flew from London in 1 hour 50 minutes.

THE ARMSTRONG SHIPYARD.

(*Concluded from page* 603.)

THE blacksmiths' shop, which, as mentioned in our last article, is situated between the angle racks and the fitting shop, occupies the greater part of a building which has a total length of 300 ft. and a width of 80 ft. The actual dimensions of the blacksmiths' shop are 250 ft. long by 80 ft. wide, the remaining portion of the building at the western end forming the blacksmiths' fitting shop. In the main smith's shop, which is illustrated in Fig. 144, annexed, the hearths are arranged along both sides of the building and a system of grouping, similar to that described in connection with the anglesmiths' shop, has been adopted. The blast is supplied by four high-pressure fans, which deliver air, at a pressure of 14 in. water gauge, through galvanised steel pipes fitted with cast-iron connections to the hearths. The smoke from the fires is carried away by uptakes connected, in convenient groups, to funnels which are sufficiently high to provide a natural draught. Practically the whole of the forgings and stampings required in the yard are produced in this shop, which is equipped with 12 power hammers. These range from 3 cwt. to 2 tons in capacity, the smaller hammers being of the electro-pneumatic type while the larger ones are worked by compressed air from the yard power station; the old Lancashire boiler, which can be distinguished on the right of Fig. 144, is used as an air reservoir for supplying the hammers. For heating heavy work a gas-fired regenerative furnace, 6 ft. 6 in. long by 4 ft. wide is provided, and there is also a smaller furnace for annealing the forgings. These furnaces, and also the larger hammers, are conveniently served by hand-power cranes supplied by Messrs. Herbert Morris, Limited, of Loughborough, and clearly shown in Fig. 144; bogie rails are also laid to facilitate the handling of the work. In the blacksmiths' fitting shop, above referred to, articles such as hand-rails, stanchions, ladders, gratings, &c., are made, and the equipment includes a punching and shearing machine with notching attachment, a capstan lathe, a band saw, and a number of drills and grinders of various types; one of the grinders is of the swinging-frame type for surface work. Part of the shop is equipped with apparatus for electric and oxy-acetylene welding.

FIG. 144. THE BLACKSMITHS' SHOP.

FIG. 145. THE SAW MILLS.

Running parallel with the engineers' fitting shop, and adjoining it on the northern side, is a large building measuring 300 ft. long by 120 ft. wide, used mainly for the storage of all kinds of finished goods required for the ships at the fitting-out quay, as well as for general use in the yard. The building is divided into two bays of equal width, and the northern bay is provided with galleries on both sides giving additional storage space for the lighter articles. At the eastern end, the two galleries are connected by a floor on which furniture, made in the adjoining cabinet-makers' shop, is stored. Two 5-ton overhead travelling cranes are provided for handling materials in this bay, and a standard gauge railway runs along the whole of its length to facilitate the reception and despatch of goods.

Across the whole width of the building at the western end is a pattern-makers' shop, which is equipped with suitable wood-working machinery and also provided with laying-out space. The remainder of the southern bay is divided into four parts, three of which form stores for cables, fittings and electrical supplies of all descriptions, while the other part is used as an electricians' workshop. This shop is used for pipework and for making fittings, &c., in connection with the electrical installations of ships, as well as for the repair of motors, arc lamps and other electrical apparatus used in the yard. It is equipped with a brass-finisher's lathe, pipe cutting and screwing machines, presses, drills, grinders, engraving machine, and other tools suitable for this class of work.

We now come to the wood-working department, which is accommodated in three buildings at the extreme northern end of the yard. As mentioned in the first article of this series, the fact that joinery work and cabinet-making form a larger proportion of merchant shipbuilding than of naval construction rendered it necessary, when changing over the Armstrong yard from the former to the latter class of work, to make certain alterations and extensions to the woodworking department. These, however, are now practically completed. Reference to the key plan of the yard, published on page 367 *ante*, will show that the saw mills are situated close to the fitting-out quay, with the timber sheds behind them and the joiners' and cabinet-makers' shop on the southern side. The saw mills form the central portion of a building having a total length of 175 ft. and a width of 120 ft. placed parallel to the quay. At the northern end of the building is a boat-builders' shop, which occupies a space measuring 120 ft. by 71 ft.; the saw mills measure 120 ft. by 82 ft. 6 in., and the greater part of the remaining portion, at the southern end, is utilised as a saw-sharpeners' shop. The only machine tools in the boat-builders' shop are a saw bench and a drilling machine, most of the work in this shop being done by hand tools; kilns are, however, provided outside the building, at the northern end, for steaming the planks preparatory to bending. In Fig. 145, annexed, we reproduce a photograph of the interior of the saw mills, in which the most notable appliance is a horizontal band saw for logs by Messrs. A. Ransome and Co., Limited, of Newark-on-Trent. This saw, which can be distinguished in our illustration, can deal with logs up to 4 ft. square, and the timber carriage, as usually employed, is of sufficient length to accommodate logs up to 40 ft. long. The carriage, however, is made in two parts, which can be separated by 20 ft., if necessary, and by thus logs up to 60 ft. in length can be dealt with. A circular saw bench, with travelling table for logs, will be noticed on the left of Fig. 145, and a heavy planing machine, by Messrs. T. Robinson and Sons, Limited, of Rochdale, is visible near the centre of the illustration; this machine, which is largely used for planing deck planks, can deal with timber up to 16 in. by 8½ in. in section. Another planer to take work up to 30 in. by 9 in., and fitted with hand and power feed, is installed, and the equipment also includes a vertical log frame, a reciprocating cross-cut saw, a band saw, two boring machines and a moulding machine. Dust and shavings are extracted by an exhaust fan which draws the dust-laden air from a pit to which the various machines are connected; the dust is used for firing a boiler which heats some of the adjacent shops.

As shown in the illustration, the saw mills are

served by a 5-ton overhead electric travelling crane, of 80 ft. span, made by Messrs. Herbert Morris, Limited, of Loughborough. The eastern end of the saw mills can be opened to full width to allow the crane to pass, and the crane rails are extended on a gantry so that the crane can be run out over the quay to lift logs from railway trucks and to pick them up from the quay when delivered from barges on the river. The logs are taken into the sawmills by the overhead crane and the sawn timber is afterwards transferred to separate seasoning kilns for hard and soft woods by means of bogie railways. There are four timber sheds, each 43 ft. in width, and ranging in length from 158 ft. to 60 ft. After treatment in the kilns, the timber is transferred to air-drying racks, and there stored until required for use. It is then cut to lengths by pendulum and circular saws provided in the sheds, and conveyed by bogie trucks and overhead runways to the joiners' and cabinet makers' shop, in which the whole of the joinery work and furniture, including chairs, required for vessels built at the yard, is constructed.

This is a two-storey building, 300 ft. long and 100 ft. wide, divided into three bays, of which the central one is 40 ft. wide and the two outer bays are each 30 ft. in width. Fig. 146, annexed, is reproduced from a photograph looking along the central bay, and from this it will be noticed that part of the upper flooring is omitted in the central portion of the shop so as to provide ample light on the ground floor. The machine tools are all situated in the bay on the right of Fig. 146, while the left-hand bay is occupied with benches, and the central bay is left clear for erecting the work. Among the more notable machines in the shop are planing and trying-up machines capable of taking timber up to 18 in. square in section, a panel planer which can deal with work up to 36 in. by 7 in., a three-drum sand-papering machine, of the type illustrated on page 787 of our last volume, for work up to 40 in. by 4 in., and a planing and moulding machine, with friction feed, which takes work up to 12 in. by 4 in. in section; all these machines are by Messrs. T. Robinson and Sons, Limited, of Rochdale. Other tools which may be mentioned are a 24-in. by 6-in. tenoning machine by Messrs. Haigh, Gruban and Co., two vertical-spindle moulding machines and a hollow chisel and chain mortising machine by Messrs. Sagar, a number of circular saw benches and band saws, and a 10-spindle boring machine. Most of the tools are belt-driven from line shafting carried on Hyatt roller bearings, but some of the larger machines have independent driving motors. Furniture constructed on the ground floor is taken, by means of an electric lift, to the upper floor, where it is polished, or otherwise finished, and stored until required, but the upper floor is now re-arranged to accommodate additional tools and benches for joiners' and cabinet-makers' work.

The few buildings in the yard which now remain to be described are situated on the southern portion of the fitting-out quay between the river and the 1,000-ft. berth. Proceeding along the quay from the southern end the first erection encountered is a shed measuring 100 ft. × 40 ft. used, so far, for overhauling and charging the accumulators to be fitted on submarine boats. Adjoining this is a space for machining rudders and steering gear, while the next building is used mainly for plumbing, coppersmiths' and sheet-iron work. This building is 64 ft. wide and has a total length of 360 ft., of which a portion 120 ft. long at the southern end is used as a carpenters' store, a workshop in connection with the installation of Diesel engines, and a general shop for the use of contractors' workmen. The plumbers' shop, which is thus 300 ft. in length, is illustrated in Fig. 147, annexed. The northern end of the shop is used for sheet-iron work the central portion for coppersmiths' work, and the southern end for plumbing work, while light sheet-iron work, such as the construction of ventilators, ventilating trunks, casings, lockers, and galley funnels, is also carried out on an upper floor at the southern end. The tool equipment includes a variety of pipe-cutting, screwing and bending machines, and shears and bending machines for sheet-iron work, as well as punching and shearing machines, grinders, drills, &c., none of which call for any special comment. There are also, of course, a number of fires and bending blocks for pipe bending. In connection with this work an interesting appliance, designed and rigged up by Messrs. Armstrong themselves, is used for packing the sand in pipes preparatory to heating and bending them. The appliance comprises a three-jaw chuck resting on a ball race mounted on a low stool and arranged so that it can be rotated about a vertical axis by means of worm and bevel gearing operated by hand.

FIG. 146. THE JOINERS' AND CABINETMAKERS' SHOP.

FIG. 147. THE PLUMBERS', COPPERSMITHS' AND SHEET METAL-WORKERS' SHOP.

Pipes ranging from 2 in. to 10 in. in diameter, previously filled with sand, are gripped in the chuck so that they stand vertically, the upper end being supported by a plate having a circular hole of approximately the same diameter as the outside diameter of the pipe. A full range of these plates is provided with holes for all sizes of pipes dealt with, and a suitable plate is slipped into a ring, which is carried by a pair of vertical channel iron guides in such a manner that it can be raised or lowered to suit pipes of any reasonable length. Another ring surrounding the pipe, and attached to brackets fitted with rollers so that it can move easily up and down the vertical guides, in the space between the supporting plate and the chuck, is provided with three pneumatic hammers, which are mounted radially on the ring at an angle of 120 deg. apart. These hammers are arranged so as to deliver a series of blows on the outside of the pipe, and, when the machine is in use, they are moved up and down the pipe by means of a wire rope passing round a drum on the same shaft as rotates the chuck. The weight of the ring and hammers is partly balanced by means of counterweights connected to the former by wire ropes passing over pulleys at the upper ends of the guide bars, but the weights are adjusted so as to give a downward tendency to the rings; compressed air is, of course, supplied to the hammers through flexible pipes. The rotary motion of the pipe, and the vertical movement of the hammers, thus subjects the whole of the external surface of the pipe to the hammer blows, and in this way the sand is thoroughly packed and consolidated.

A considerable amount of welding is done in connection with pipe work, both by the Quasi-Arc and oxy-acetylene processes, the steel plate enclosure seen in the foreground in Fig. 147, above, being used for this work. The acetylene generators are housed in a shed outside the building at the northern end.

The whole of the electric energy required in the

yard is taken from the system of the Newcastle Electric Supply Company, so that no generating machinery is employed. The electrical installation is, however, very extensive as the total brake horse-power of the motors in the yard amounts to about 10,000, and electric energy is also used for lighting, welding, cooking and other purposes. Three-phase current is supplied at 6,000 volts and 40 cycles, to three sub-stations in the yard, in which it is stepped down by static transformers to 440 volts for distribution to the shops. The sub-stations are conveniently situated, one near the western end of the general stores building supplying the shops in the northern part of the yard, another near the head of the fourth building berth supplying the platers' shed and other plant in the neighbourhood of the berths, and the third in the power-station building near the centre of the fitting-out quay supplying the machinery in the power station, which we shall deal with later. The exact location of each of the sub-stations is clearly shown on the key plan of the yard, on page 367 *ante*. Two oil-cooled static transformers, each of 600 k.v.a. capacity, are installed in each of the sub-stations, together with the necessary high-tension and low-tension switch gear, which is of the Reyrolle ironclad type. Small subsidiary transformer stations are also provided on the jetties between the large building berths for lighting the latter, at 110 volts, and also the ships under construction. In addition to these, a number of transformers have been installed in most of the larger shops to take current from the power mains at 440 volts and reduce it to 110 volts for lighting; by this means the losses arising from long lengths of low-tension cable are avoided. There are also a number of portable motor generators used on the fitting-out quay to supply direct current, at various voltages, to the switchboards of vessels approaching completion. Direct current is also used, both for lighting and power, in the woodworking department, since the stroboscopic effect due to alternating current may cause the rapidly-rotating cutters to appear stationary, and thus give rise to accidents. The incoming cables to the main sub-stations are laid in duplicate, and the sub-stations are all interconnected so that, in an emergency, the whole of the yard can be supplied by any one of the sub-stations; it is thus practically impossible for an accident to involve a complete shut down. The whole of the cables in the yard are of the armoured type laid underground in creosoted wooden troughs.

The power station building, which is used mainly for the supply of compressed air and hydraulic power, measures 150 ft. long and 75 ft. wide, and is placed parallel with the fitting-out quay near the centre of the latter. A portion of the building, 38 ft. in length, at the southern end, is used as a millwrights' shop, in which general repairs to the yard plant are effected; the shop contains a few lathes, shapers, drills and other tools suitable for this class of work. The remainder of the building forms the power station, in a corner of which one of the three sub-stations, above referred to, is located. Fig. 148, annexed, shows the interior of the power station, and the brickwork compartment, which contains the sub-station plant, can be seen on the left-hand side of the illustration. The high-tension switches for the incoming lines, and for the mains connecting up the other sub-stations, are placed above the transformers, and are operated from the gallery visible in the illustration. The low-tension switchboard is placed on the floor under the gallery, and consists of 13 ironclad pedestal-type panels, two of which connect the secondaries of the transformers to the 'bus-bars, while the others control the distribution of the current to the motors driving the pumps and compressors; all the switch gear is of Messrs. Reyrolles' manufacture.

FIG. 148. THE POWER STATION.

The air-compressing plant comprises eight electrically-driven units, some of which can be distinguished in the background of Fig. 148. These supply air at a pressure of 100 lb. per square inch for operating power hammers, portable pneumatic tools and other appliances used in the yard. The largest compressor, by Messrs. Belliss and Morcom, Limited, of Birmingham, is capable of compressing 3,000 cub. ft. of free air per minute, and is directly coupled to a Bruce Peebles induction motor of 650 h.p. A second Belliss and Morcom machine, driven by a 400-h.p. Sandycroft "Cascade" motor, has a capacity of 2,200 cub. ft. per minute, and there is another compressor of the same capacity by Messrs. Alley and Maclellan, Limited, of Glasgow, driven by a Westinghouse induction motor. Of the other compressors installed, all of which were built by Messrs. Alley and Maclellan, two have capacities of 2,200 cub. ft. and 1,200 cub. ft. per minute, respectively, while the three remaining units are each capable of compressing 600 cub. ft. per minute. The three small compressors are belt-driven from Armstrong motors, while the other two machines are both directly coupled, the larger to a 400-h.p. cascade motor, and the smaller to a 260-h.p. Westinghouse induction motor. Air is delivered into a vertical cylindrical receiver, 30 ft. long and 8 ft. in diameter, placed in a separate compartment of the power station building at the northern end. From this it is distributed by 14-in. underground mains to all parts of the yard, the diameter of the mains diminishing to 9 in. at the most distant points. A 6-in. main, with branches at convenient intervals, is run down the sides of each of the large berths, and arrangements are also made for the supply of air to vessels at the fitting-out quay. At various points in the yard where a particularly large demand for air occurs, such as the blacksmiths' shop and platers' shed, air receivers are provided of sufficient capacity to render the pressure fluctuations negligible.

Hydraulic power is supplied by the three sets of pumps which can be seen in Fig. 148. These pumps, which are of Messrs. Armstrong's own construction, are of the three-throw type, and are each capable of delivering 90 gallons of water per minute against a working pressure of 900 lb. per square inch. They are driven through double-reduction helical gearing by 75-h.p. motors, two of which were made by Messrs. Armstrong and the other by the Westinghouse Company. The motors are automatically controlled by tappet switches actuated by the rise and fall of the accumulator, which is placed by the side of the air receiver in the compartment at the northern end of the building; the accumulator has a ram 18 in. in diameter with a stroke of 20 ft. Hydraulic power is distributed throughout the yard by 6-in. underground mains, and the exhaust is returned by an 8-in. pipe to a

tank in the power station. The only other plant in the power station consists of two electrically-driven centrifugal pumps, which supply water for general use in the yard and also for testing tanks and watertight compartments of vessels under construction on the berths. These pumps, which are placed in the well shown in the foreground of Fig. 148, also circulate the cooling water for the compressors. For use in connection with the overhauling and repairing of the plant in the power station, two 10-ton overhead travelling cranes, operated by hand power, are provided. One set of crane rails is extended into the millwright shop, so that heavy machine parts can be transferred there for attention and returned with the minimum expenditure of time and trouble.

Having now completed our account of the yard and its equipment, it only remains to mention the names of the men who are now responsible for its working. The general management of the Armstrong yard, and also of Messrs. Armstrong's other yard for mercantile work at Walker, is in the hands of Mr. H. G. Williams, with whom Mr. R. Saxton White acts in a consulting capacity. The commercial manager of the Armstrong yard is Mr. E. L. Orde, while the constructional work is under the direction of Mr. F. E. W. Coller. We have already mentioned in our first article, on page 368 *ante*, the part played by Sir George Carter (now of Messrs. Cammell Laird) and the late Mr. J. R. Perrett, in the early history of the yard, and to these names we now wish to add that of Mr. Harold Thomson, who was responsible for the installation of the machinery. The whole of the plant is now in charge of Mr. J. W. Gibbeson, the engineer superintendent of the yard, to whom we are indebted for much of the information on which our articles have been based. In conclusion, we would also express to Mr. Williams, our appreciation of the facilities placed at our disposal on the occasion of our recent visit to the yard.

NOTE ON "THE BALL TEST."*

By THOMAS BAKER, D.Sc., M.Met., F.I.C., and THOMAS F. RUSSELL, Associate in Metallurgy.

SINCE its introduction in 1900, the Brinell test has served as the basis for many investigations, in the course of which many new machines have been devised for carrying it out, and several relations between the factors involved firmly established.

Meyer† in 1908, as is well known, found that for 28 different metals and alloys the relation between the load L on the ball and the diameter of the impression d was in every case of the form $L = a\,d^n$, and that the mean pressure per unit area, $\frac{4\,L}{\pi\,d^2}$, was constant for a given angle of impression whatever the diameter of the ball. The coefficients a and n vary with different sized balls for the same material. The hardness number (P_m) is defined by him as $\frac{4\,L}{\pi\,d^2} = \frac{4\,a\,d^{n-2}}{\pi}$, hence for materials in which $n = 2$, P_m is independent of the load, the angle of impression, and the size of the ball.

Towards the end of the same year Kürth‡ confirmed in the case of copper and nickel the relation established by Meyer, and concluded that for a given metal the value of n depends on its condition as regards strain, and that it has its maximum value when the material is in the annealed condition. By comparing hardness measurements (constant diameter and angle of impression) with the yield-point, he also found that these two properties were related to one another by a straight-line law over the whole range of hardening by tension. These lines for different sized impressions intersect in a point corresponding to the breaking load divided by the contracted area. The curves showing the relation between the ratio of the tensile strength to hardness and the exponent n coincide for nickel, copper, and steel low in carbon. Hence it is concluded that when materials are cold worked to corresponding degrees as defined by their having equal values of n, they also have equal values for the ratio of the tensile strength to hardness.

Moore§, in 1909, following up Meyer's work, suggested that the selected standard angle should give a diameter of impression equal to the radius of the ball, and deduced the following relation for the hardness number determined under these conditions:

$$\text{Hardness number} = \frac{16\,L\,D^{n-2}}{\pi\,(2\,d)^n}$$

in which L is the load, D the diameter of the ball, d the diameter of the impression, and n the constant, the value of which can be deduced from two impressions using the same ball under different loads. In this case the hardness number is independent of the size of the ball. It is also stated that $n - 2$ is a measure of the capacity for hardening by cold work.

In papers entitled "The Falling Ball Test," published in 1911 by J. J. Schneider,* some interesting results on dynamic hardness testing are described. Using a 10-mm. ball falling from various heights, and working on 12 different metals and alloys, he found that the striking energy was related to the diameter of the indentation by the formula $E = a\,d^n$. For the metals tested, a varied between 425 and 3,075, and n between 4·02 and 4·20.

An almost similar series of experiments, carried out by Professor Edwards and Mr. Willis† in 1918, established the formula $d = C\,E^n$, which is readily converted into the form $E = c_1\,d^{n_1}$. Their series of metals covered a range from aluminium to hardened steel; the value of n varied between 0·24 and 0·27, but they finally concluded that it should be 0·25 in every case: i.e., that n_1 should be 4. In view of Schneider's work and some results which will be given later, the authors are of opinion that n should be calculated for each metal.

It is also interesting to note that this last-named writer found that the energy absorbed, or the total energy E minus the energy of rebound E_1 was related to the diameter of the impression by the expression $E - E_1 = a_2\,d^{n_2}$. For the metals tested a_2 varied between 400 and 1,453, and n_2 between 4·035 and 4·50. It is also stated that $E + E_1 = c\,d^4$, but the exact significance of this relation is not readily apparent.

In the discussion on Mr. Shore's paper on "Hardness Testing" before the Iron and Steel Institute in 1918, one of the authors showed that the calculated volume of the indentation in the static test is connected with the load on the ball by the relation $L = b\,V^m$. If this is combined with Meyer's formula $L = a\,d^n$, the volume may be expressed by:

$$V = \sqrt[m]{\frac{a}{b}}\,d^{\frac{n}{m}} = p\,d^q$$

where p and q are constants. The values of a, b, m and n, calculated from 10 different experiments when substituted in this relation, give:

$$V = 0{\cdot}00939\,d^{3{\cdot}084}$$

The graph of this expression is plotted in Fig. 1, and also that of the expression:

$$V = \frac{\pi}{3}\left(r - \sqrt{r^2 - \frac{d^2}{4}}\right)^2\left(2\,r + \sqrt{r^2 - \frac{d^2}{4}}\right)$$

where r is the radius of the ball.

Fig. 1. GRAPHS OF THE EQUATIONS.

$V = 0{\cdot}009392\,d^{4{\cdot}084}$ . . . . . .

$V = \frac{\pi}{3}\left(r - \sqrt{r^2 - \frac{d^2}{4}}\right)^2\left(2r + \sqrt{r^2 - \frac{d^2}{4}}\right)$

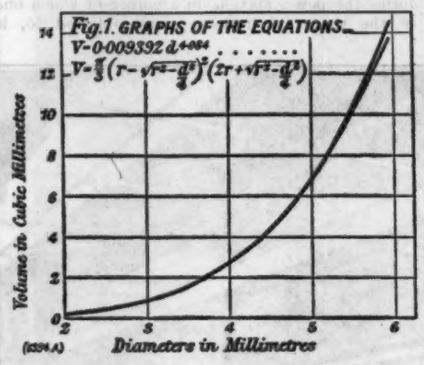


Fig. 2. SHOWING RELATIVE POSITION OF THE TEST-PIECES

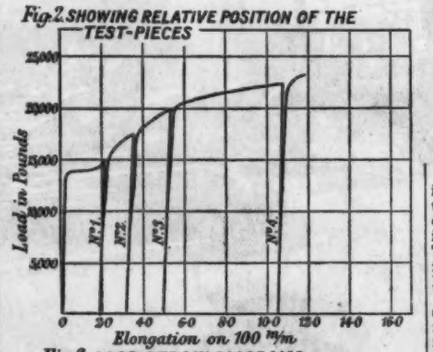


Fig. 3. LOAD-STRAIN DIAGRAMS.

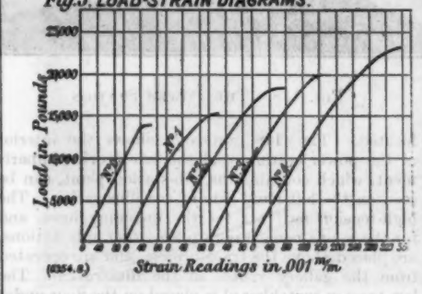


Fig. 4. RELATION BETWEEN BRINELL NUMBER AND LOAD.

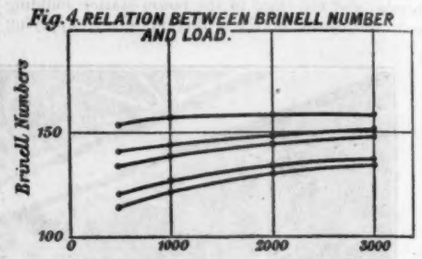
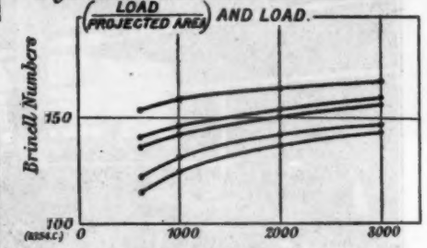


Fig. 5. RELATION BETWEEN BALL NUMBER $\left(\frac{\text{LOAD}}{\text{PROJECTED AREA}}\right)$ AND LOAD.



For diameters of impressions, which ordinarily occur in practice, i.e., between 2 mm. and 5 mm., it is clear that the two values of V are in agreement. (For any other range of diameters the volume can be expressed in a similar way with slightly altered values of p and q.) This fact shows that the apparently dissimilar relations found by Batson,* and by Edwards and Willis, viz., $E = H\,V$ and $E = c\,d^4$, are really one and the same.

The object of this investigation was to ascertain the significance of the constants a and n, b and m in the relations $L = b\,V^m$ and $L = a\,d^n$, and to correlate as far as possible any variations in them with changes in other physical properties of the material under investigation. It is apparent that as m or n varies, so there will be a variation in the work necessary to give similar impressions; thus we may have two pieces of steel, which require equal loads to displace unit volume, but which require different amounts of work for the process.

For the experiments a mild steel containing 0·24 per cent. carbon was selected, and several pieces of it, 10 in. long by 1¼ in. diameter, after heating to 880 deg. C. and allowed to cool slowly, were machined into test-bars 0·9375 in. diameter. Four of these were respectively strained in tension, for a few minutes, under loads of 15,000 lb., 17,500 lb., 20,000 lb. and 22,500 lb., and then unloaded. The actual positions of the four strained bars numbered 1 to 4 on the load-strain diagram of one of the original bars are shown in Fig. 2. Whilst under stress, the diameters of bars were measured and the actual stresses on the specimens calculated. After a rest of 24 hours and remeasurement, the bars were again strained to a point just over their acquired yield-point, careful extensometer measurements were made, and from the figures obtained the load strain diagrams in Fig. 3 were plotted. It will be observed that the limit of proportionality is very much lower in the strained bars than in the unstrained one, and that the distance between the limit and yield-point is considerably augmented by straining. All the stressed bars, and one numbered 0 which had not been initially strained, were milled down to the axial plane and two ball impressions, for each of the loads of 500 kg., 1,000 kg., 2,000 kg. and 3,000 kg., made down the centre of each bar.

At least two observers measured these impressions to 0·01 mm., but there was no appreciable variation between them; the values have, however, been averaged for each load. The results of these measurements are given in Table I and shown graphically in Figs. 4 and 5. These curves display very clearly the effect of cold work in flattening out the curve, showing the relation between the Brinell number and the load, and also to a somewhat lesser extent that between what we have called the ball number and the load.

If, now, the relations $L = b\,V^m$ and $L = a\,d^n$ apply,

---

* Paper read before the Iron and Steel Institute on May 7, 1920.

† E. Meyer: "Hardness Testing and Hardness." *Zeitschrift des Vereines deutscher Ingenieure*, April 25, May 9, May 23, 1908.

‡ Alfred Kürth: "Relation between Hardness, Elastic Limit, and Energy of Tenacious Metals." *Zeitschrift des Vereines deutscher Ingenieure*, September 26, October 3, 1908.

§ H. Moore: "Investigations on the Brinell Method of Determining Hardness." Proceedings of the International Association for Testing Materials, 1909.

* J. J. Schneider: "The Falling Ball Test." *Zeitschrift des Vereines deutscher Ingenieure*, vol. liv, pages 1631 to 1637.

† C. A. Edwards and F. W. Willis: "A Law Governing the Resistance to Penetration of Metals when Tested by Impact with a 10-mm. Steel Ball." Proceedings of the Institution of Mechanical Engineers, June, 1918.

* R. G. C. Batson: "Value of the Indentation Method in the Determination of Hardness." Proceedings of the Institution of Mechanical Engineers, October, 1918.

the logarithmic forms of these equations should give straight lines when log L is plotted against either log V or log d. That this is the case is shown by the curves plotted in Figs. 6 and 7 from data in Table I. The inclination of these lines to the abscissa is a measure of the index m or n. The calculated results are shown in Table II, and in order to eliminate as far as possible the personal factor, the values were not taken from the diagram but determined by "the method of least squares." It is especially interesting to note that the indices of V and d gradually diminish the more the metal is initially strained. Confirmation of this fact is to some extent given by the tensile test. It is well established that the Brinell test is a handy means of estimating the nominal maximum stress of a metal in certain cases; but exactly what is the basis of the relation between the two does not appear to have been explained so far as the authors are aware.

The tensile test is always regarded as of first-rate importance, and rightly so, but when a load-strain diagram from this test is critically examined, it is by no means so satisfactory as at first sight appears. The ordinate is load and cannot be adversely criticised, but the abscissa is of too arbitrary a nature and represents generally the extension between two points on the test bar chosen by the operator. The weakness lies in the

Fig. 6. SHOWING STRAIGHT LINE RELATION BETWEEN LOG L AND LOG d.

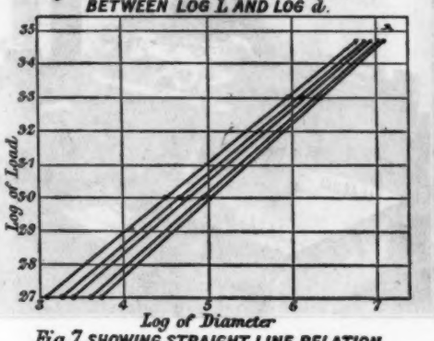
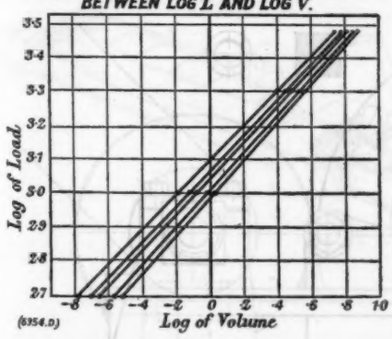


Fig. 7. SHOWING STRAIGHT LINE RELATION BETWEEN LOG L AND LOG V.



fact that the rate of elongation between these two points is not constant. The area between the load strain curve and the abscissa gives the work necessary to rupture a test-piece of a length equal to that between the gauge points. It is obvious that the specific work of deformation or work per unit volume varies from a maximum at the point of rupture to a minimum at the gauge points, so that the work represented by the diagram is the summation of all these quantities and is quite useless except for the crudest of comparisons.

The arbitrary nature of the abscissa can be eliminated by imagining the gauge points at such a distance apart that the sides of the test-piece remain parallel throughout the test and deducing the length from measurement of the diameter, under the assumption that the density of the material does not alter to any appreciable extent. The volume of the test-piece under consideration then remains constant.

Let A = original cross-section of the bar,
a = contracted cross-section of the bar,
b = length of bar under consideration before stretching,
c = length of bar under consideration after stretching,

then $a\,c = A\,b$,

$$c = \frac{A\,b}{a}$$

Increase of length of the bar $= \left(\frac{A\,b}{a} - b\right) = b\left(\frac{A-a}{a}\right)$

It is therefore only necessary to plot the load against the contraction of area divided by the reduced area in order to obtain a diagram free from the objection mentioned above. Unfortunately no more of the steel on which the foregoing tests were made was available; recourse had therefore to be made to another cast. Tests were carried out in the manner indicated, and no difficulty experienced in getting from 30 to 40 readings of the diameter without in any way interfering with the normal progress of the test.

The results of these tests, marked A to F, are plotted in Fig. 8 in the form of load-strain, and in Fig. 9 as stress-strain diagrams. When plotted in this way the load-strain diagram has a much more definite significance than when plotted in the usual way, since its area is now a measure of the work which must be expended on unit volume before fracture takes place. Turning to the stress-strain curves, it will be noticed at once that they present no point of inflection in the upper part of the curve, such as is shown in diagrams where the extensions on a test length of 2 in. or more are used for the abscissa of the curve.

If the test-bar be loaded to A, Fig. 9, and then unloaded, it is generally assumed that the elastic limit is increased to this point. This may or may not be the case according to circumstances. It can, however, be assumed that the stress indicated by the point A must be exceeded before any further flow of the metal will take place. The ordinates of the curve may therefore be regarded as the "stress intensity of flow" of the material under examination. As this quantity increases, the flatter becomes the curve, *i.e.*, the nearer the metal approaches a state where it would have a constant "stress intensity of flow," or one in which any additional

Fig. 8. LOAD-STRAIN DIAGRAM

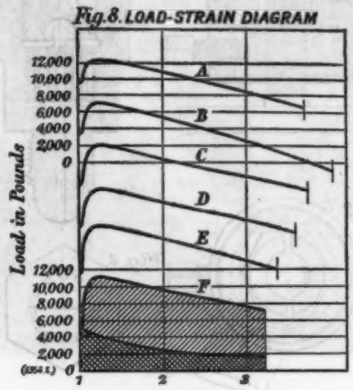
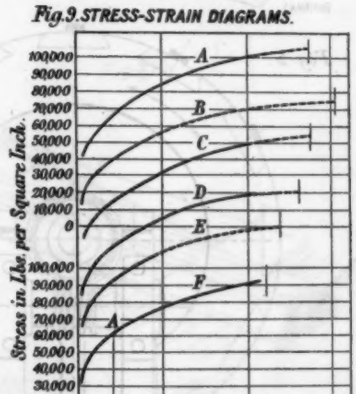


Fig. 9. STRESS-STRAIN DIAGRAMS.



cold work would fail to produce any hardening effect.

It has already been shown that the index n in the formula $L = a\,d^n$ gradually diminishes as the cold work in the specimen increases, and that it approximates to a value equal to 2. If it were possible to reach this value, the ball number would be constant, *i.e.*, the nearer the index approaches the value 2, the nearer the metal approaches that in which there would be a constant stress intensity of flow; hence in this value there is a valuable indication as to the state of a metal with respect to cold work. Similar conclusions are arrived at from the consideration of the formula $L = b\,V^m$. The constant a and b indicate respectively the values of the loads necessary to produce an impression of unit diameter and that to give one of unit volume.

If there were no hardening effect due to cold work, the stress intensity of flow would remain constant once the primitive yield point was passed, and would remain so until fracture took place. This would be represented on the load-strain diagram, plotted in the manner just described, by a line as indicated in the bottom diagram of Fig. 8. The area bounded by this curve represents the work expended in drawing out the metal, and the difference between this area and that bounded by the curve showing the relation between the load and strain when work hardening does take place, should represent the work which goes to increase the internal energy of the metal, and which no doubt will be claimed by the supporters of the amorphous phase theory as the latent heat of formation of this substance. These ideas are embodied in Fig. 8. This absorbed energy ought to manifest itself when the material returns to its original state. It would be premature to go further into this question at this point, but work is proceeding along these lines.

To sum up, it is possible by the use of these formulæ to calculate the load necessary to give an impression of any required size, when the values of the constants are known. These can easily be obtained from the measurement of two impressions made by the same ball under different loads. In the value of the index n there is also an indication of the state of the metal with respect to cold work.

TABLE I.

	Diameter in Mm.	Volume.	Brinell No.	Ball No.
No. 0.		*No Initial Stress.*		
Load of 500 kg. ..	2·35	0·3049	114·0	115·0
Load of 1,000 kg. ..	3·20	1·067	121·0	124·4
Load of 2,000 kg. ..	4·32	3·657	130·0	136·5
Load of 3,000 kg. ..	5·14	7·567	134·0	144·0
No. 1.		*After Initial Stress of 19·77 Tons.*		
Load of 500 kg. ..	2·29	0·2799	118·7	121·4
Load of 1,000 kg. ..	3·12	0·9623	127·5	130·8
Load of 2,000 kg. ..	4·23	3·3445	132·5	142·3
Load of 3,000 kg. ..	5·11	7·381	136·0	146·0
No. 2.		*After Initial Stress of 23·36 Tons.*		
Load of 500 kg. ..	2·17	0·2214	133·5	135·1
Load of 1,000 kg. ..	3·00	0·8204	138·1	141·4
Load of 2,000 kg. ..	4·10	2·946	144·8	151·5
Load of 3,000 kg. ..	4·93	6·348	148·9	157·1
No. 3.		*After Initial Stress of 27·15 Tons.*		
Load of 500 kg. ..	2·12	0·2012	140·1	141·6
Load of 1,000 kg. ..	2·95	0·7663	143·1	146·4
Load of 2,000 kg. ..	4·07	2·859	147·1	153·7
Load of 3,000 kg. ..	4·88	6·081	150·2	160·4
No. 4.		*After Initial Stress of 33·04 Tons.*		
Load of 500 kg. ..	2·03	0·1690	152·9	154·0
Load of 1,000 kg. ..	2·82	0·6378	156·9	160·0
Load of 2,000 kg. ..	3·94	2·5000	157·4	164·0
Load of 3,000 kg. ..	4·77	5·5260	157·7	168·0

TABLE II.

No.	State.	Normal Max. Stress.	Brinell No.	Max. Stress Brinell No.	$L = b\,V^m$	$L = a\,d^n$
0	880 deg. C. cooled in muffle ..	30·80	134	0·229	$968\ V^{0\cdot687}$	$70d^{1\cdot988}$
1	After stressing with 19·77 tons	31·39	136	0·231	$1{,}018\ V^{0\cdot643}$	$79{\cdot}7d^{1\cdot956}$
2	After stressing with 23·36 tons	31·79	147	0·216	$1{,}122\ V^{0\cdot633}$	$91{\cdot}6d^{1\cdot986}$
3	After stressing with 27·15 tons	32·33	150	0·215	$1{,}156\ V^{0\cdot632}$	$98{\cdot}9d^{1\cdot947}$
4	After stressing with 33·04 tons	34·05	158	0·215	$1{,}250\ V^{0\cdot612}$	$113{\cdot}6d^{1\cdot935}$

The authors desire to thank Messrs. Steel, Peech and Tozer for permission to publish the results of this investigation, and Mr. J. Stead and other members of the laboratory staff for their hearty co-operation in the work.

APPENDIX.

Occasions frequently arise when a Brinell hardness number is required on a piece of material which is either too small or too thin for the application of the standard test, and yet a figure is required comparable with that which would have been obtained had the standard test been applied. In such cases the following method has met with much success in the author's laboratory.

The Brinell hardness number H is expressed by $H = \frac{L}{A}$

(L = load on the ball and A = area of the spherical surface of the impression). The area can be determined from the measurement of either the depth or the diameter of the indentation. Of the two the depth measurement lends itself more readily to mathematical treatment and the final result can be easily expressed in terms of the diameter of the impression. Thus if d is the diameter of the ball and h the depth of the impression, the following relation is obtained for the Brinell hardness number:

$$H = \frac{L}{\pi\,d\,h}$$

Multiply each side by $\frac{h}{d}$, then

$$\frac{H\,h}{d} = \frac{L}{\pi\,d^2}.$$

The second member of this expression is a constant quantity and depends only on the ratio of L to d^2 and not at all on the material whose hardness is required. If another determination is made with a ball of different diameter and the load so adjusted that the above ratio has the same value as in the previous test, then:

$$\frac{H\,h}{d} = \frac{H_1\,h_1}{d_1}$$

If the values of H and H_1 are to be equal, then:

$$\frac{h}{d} = \frac{h_1}{d_1}.$$

By substituting for h and h_1 their equivalents in terms

of D and D_1, the diameters of the impressions, it readily follows that:

$$\frac{D}{d} = \frac{D_1}{d_1} \text{ or } D = D_1 \frac{d}{d_1}.$$

Hence if $\frac{L}{d^2}$ is maintained constant, the ratio of the diameters of the impressions produced by different balls should be equal to that existing between the diameters of the balls.

The results in Table III have been obtained by this method and show clearly that consistent results can be obtained over the range of balls indicated. Other cases

TABLE III.

Steel.	Diameter of Ball.	Diameter of Imp. D_1.	Ratio $\frac{d}{d_1}$.	Value of $D_1 \times \frac{d}{d_1}$	Brinell No.	Load.
	mm.	mm.				kg.
A	10·00	6·3	1·0	6·30	85	3,000·0
	7·00	4·4	1·43	6·29	85	1,470·0
	5·00	3·13	2·00	6·26	87	750·0
	1·19	0·748	8·40	6·28	86	42·5
B	10·00	4·75	1·00	4·75	159	3,000·0
	7·00	3·33	1·43	4·76	158	1,470·0
	5·00	2·35	2·00	4·70	163	750·0
	1·19	0·567	8·40	4·76	158	42·5
C	10·00	3·48	1·00	3·48	306	3,000·0
	7·00	2·43	1·43	3·47	308	1,470·0
	5·00	1·73	2·00	3·46	310	750·0
	1·19	0·411	8·40	3·45	311	42·5

present themselves, in which the size of the object renders the use of the ordinary machine impossible. On such occasions the method described below may be used; the limitations of it, however, must not be lost sight of if accurate results are desired. If a ball be placed between two plates, one of known, the other of unknown hardness, and pressure applied in such a manner that an impression is made on each plate, then since the pressure and the ball are the same for both plates,

$$H A = L = H' A'$$

(where H, L and A have reference to the plate of known hardness, and H′, L and A′ to the plate of unknown hardness), hence:

$$H' = H \frac{A}{A'}.$$

If a 10-mm. ball has been used there is no need to calculate the values of A and A′, since they are inversely proportional to the hardness numbers, which are found opposite the values of the diameters of the respective impressions in an ordinary Brinell table. Then:

$$H' = H \frac{\Delta'}{\Delta}$$

(where Δ′ and Δ are the hardness numbers corresponding to the impressions on the unknown and known plates respectively).

In the application of this method the following results have been obtained (Table IV). In these experiments the load was steadily applied in a press. If, however,

TABLE IV.

Impression on Standard Plate Δ	Impression on Test Plate Δ′	Ratio $\frac{\Delta'}{\Delta} \times$ H.	Brinell No. H′.	Brinell No. under Standard Conditions
mm.	mm.			
3·7 = 269	4·63 = 168	0·624×269	168	165
5·7 = 107	4·25 = 201	1·878×88	165	
3·85 = 248	4·30 = 197	0·794×209	166	
3·9 = 241	3·30 = 341	1·415×209	295	293
5·8 = 103	3·30 = 341	3·310× 88	291	
3·4 = 321	3·30 = 341	1·062×277	294	

instead of applying it in this manner it is applied impulsively, as by a blow with a hammer, results are obtained which differ from those obtained under a static load (Table V).

TABLE V.

Impression on Standard Plate Δ.	Impression on Test Plate Δ.	Ratio $\frac{\Delta'}{\Delta} \times$ H.	Brinell No. H′.	True Brinell No.	Difference.
mm.	mm.				
3·1 = 388	3·8 = 255	0·657×269	177	166	+11
3·3 = 341	4·05 = 223	0·653×269	176	166	+10
2·8 = 477	3·45 = 311	0·652×269	175	166	+ 9
3·48 = 306	3·85 = 248	0·810×209	169	166	+ 3
2·95 = 429	3·25 = 352	0·820×209	170	166	+ 4
4·30 = 197	3·60 = 285	1·446× 88	127	166	−39
4·20 = 207	3·50 = 302	1·459× 88	128	166	−38

When the standard plate is softer than the test plate, the hardness number is less than it ought to be, whilst if it is harder, the number is greater than it ought to be. Consequently, if figures comparable with those obtained by the standard Brinell test are required, the test plate must be of approximately the same hardness as that of the material whose hardness is desired.

ENCOURAGEMENT OF INVENTION IN WORKSHOP PRACTICE.*

By Mr. J. HAMILTON GIBSON, O.B.E., Member.

In the daily round of operations in an engineers' workshop there is abundant scope for the introduction of improvements. No shop is so perfectly equipped and organised that it is incapable of improvement somewhere or somehow, for there is no such thing as perfection or finality in good engineering practice. The best establishments are those that keep an open mind and a keen perception for any hint that promises something better.

In this consideration care must be taken to distinguish between manufacturing and engineering. Manufacturing implies mass production and repetition work where methods must necessarily become stereotyped, and changes cannot be countenanced except under very special circumstances. On the other hand a general engineering works—especially one that undertakes repairs—is in a very different category, and marine engine shops, where allied with shipyards dealing with old and new work, are constantly being brought up against interesting problems that tax the initiative and resources of the staff to the utmost.

Let us in the first place do justice to the designers and draughtsmen, who are always expected to go one better than their last effort; and, to their credit be it said, generally succeed. From their practical experience (and all engineer draughtsmen must go through the mill of actual work) these men know exactly where they can save weight here, or a framespace there, or eliminate a redundant stay or link somewhere else, without impairing the efficiency of the job. It is a poor draughtsman who cannot earn far more than his pay represents, by economies such as are here indicated; but after all, it is merely his normal work to go on day by day laying out, and piecing together, and then checking suggested improvements. Now just as the best draughtsmen are those who have had the best preliminary practical training, so also the best foremen and shop managers are the men who have learned something of the importance of design. It is not enough that they should be able to read and interpret a drawing. They ought to know why and wherefore certain forms of construction are shown, and if they do not, or if the reason is obscure, or if it appears that a simpler method could be devised, then they should be encouraged to discuss the matter with the draughtsman, and whatever is decided should be embodied at once on the drawing. By these means, and by full and frank discussion, mistakes are obviated, and real improvements often effected. During the author's experience as engineering manager, he always insisted on the ironfoundry being consulted at the outset of a job, and the patterns being made accordingly. It seems a small matter; but when one has to go far afield for castings—to the Clyde, to the North-East Coast, or the Midlands—it is astonishing to find the variations in foundry practice that obtains; and it is just as easy to make the patterns one way as another, so long as one knows beforehand. This is perhaps a digression, but it serves to emphasise the importance of close co-operation between design and construction.

Improvements emanating from the drawing office may therefore be treated as all in a day's work. The economies effected are not always immediately obvious, and it is sometimes difficult to assess their true value, unless of course it happens to be something really new and novel, which may develop into a real invention. In the workshop, however, it is different. The management continually finds itself up against the necessity of devising some new method to speed up production of some essential part to keep pace with the rest of the work, or some little mechanical contrivance is put into operation that proves to be much superior to existing methods, and the improvement can be expressed at once in terms of time saved, and money gained.

In recent years, several firms have developed systems of bonuses and rewards for such improvements; but the best scheme in the author's opinion, and one that so far appears to work most satisfactorily from the employee's point of view, is to secure the invention by a provisional patent taken out in the joint names of the firm and the employee. The firm pays the patent fees, and if the "improvement" (which is the legal term,

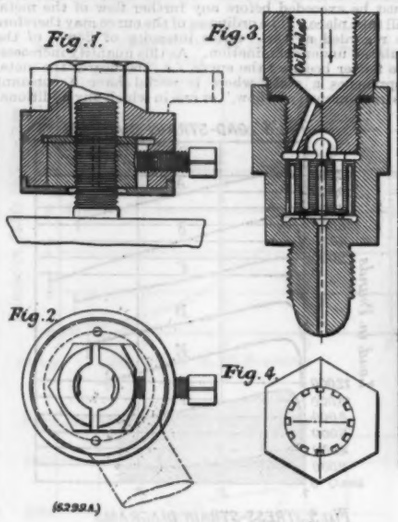
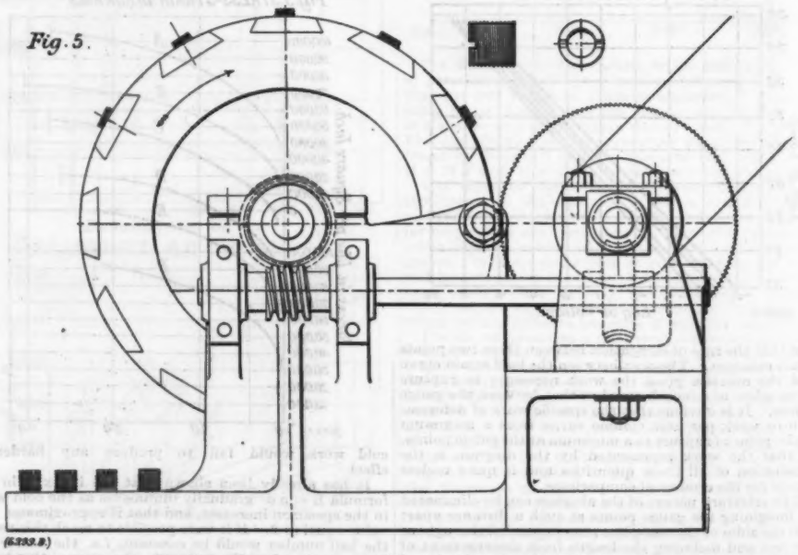


FIG. 6.



* Paper read before the Institute of Marine Engineers, Incorporated, March 16.

by the way, for all such inventions) has already resulted in a real economy, a cash payment to the employee is made on account. In many cases the improved appliance is of such a nature that the firm where it originates cannot very well market the article; and it is then handed over to another firm who specialise in such fittings, any royalties that accrue being divided with a generous bias in favour of the inventor. The employee is therefore protected from the anxiety and fear of infringement, which is always a possibility where a single individual is concerned. Moreover he has the advantage of the free expert advice and assistance of the firm's regular patent agent, and has the satisfaction of knowing that if there is anything at all in his invention, he is sure to make something out of it. On the expiry of the provisional period the patent is completed at the firm's expense; or it may be dropped if found to be valueless. But in the latter case the employee is free to complete the patent himself if he so desires. The patent is thus secured for four years (or longer under the new Act) a sufficient period to establish its value, when annual taxes become due. Altogether the scheme is extremely fair and generous, and in strong contrast to the old days when an employee who presumed to invent and patent anything, even at his own expense, was looked upon with a certain amount of disfavour.

In this connection the author well remembers the experience of an intimate friend of his, which shows how far we have advanced in such matters. As works manager he was responsible for an Indian Government contract involving certain stringent tests. The first batch of material failed to pass the tests; but after many sleepless nights and several experiments the manager hit on a method of manufacture which saved the situation. The material, some thousands of pounds worth, triumphantly passed all the tests and the customers were well satisfied. At the next Board Meeting the works manager was called before the directors. He naturally expected to be complimented on his success, as he had in effect invented a new process which meant many future orders. Imagine his surprise when the enormity of his shortcomings was pointed out to him, and he was reprimanded for not thinking of the process before!

That was twenty-five years ago. Employers have more sense nowadays. They recognise that a man is something more than a mere machine; that he is a thinking being, and that if by a flash of inspiration or exceptional skill he produces something outside and beyond his usual routine he should get some credit for it. The inventive instinct is strong in most workmen, engineers especially. There is something in human nature that revolts at unnecessary labour, even if it does at first sight appear to provide work for a greater number of hands. The story of the (apparently) lazy boy who invented the first valve gear, by connecting the tappets with string to the moving beam, has been duplicated under similar circumstances over and over again in engineering history. We don't suppose that the lad worried much about losing his job as valve tender. He would be sure to make good at more congenial work, and meanwhile the steam engine industry has received a decided fillip that meant employment for many more individuals.

The inventor does not usually take account of such trifles as the temporary displacement of labour when a brain-wave overtakes him. He has created something that did not exist before, and one must confess that invention has a fascination all its own that is incomparable. If it happens to be something really useful all the better. And no one is more likely to invent useful devices than the man who is working among the multitudinous apparatus of a modern shipyard, where constant improvisation of jigs and fixtures and appliances is the order of the day.

Let us now take a few examples that have come to the author's notice. We will see how the various devices came to be evolved, the uses to which they have been put, and perhaps the mere recital will suggest similar "gadgets" that members present may have come across in their experience.

1. The cover studs of cylinders, turbine casings, and large valve boxes are apt to get damaged during the time they are knocking about an engine shop waiting for the final assembling of a set of machinery. It was the practice to go over such studs, before completion, with a solid die nut to restore the threads as far as possible. A fitter engaged on this work noticed that frequently the die nut got across the threads and the stud was irretrievably ruined, necessitating its withdrawal and replacement by a new stud. He therefore made a split-die nut, Figs. 1 and 2, with threads backed-off the reverse way, dropped it over the stud, set it up on to the good threads by a grub screw and then screwed it off the stud with a left-hand motion. Result, entirely satisfactory, practically all damaged studs saved, and much time and trouble obviated. The firm of tool makers who took over the appliance, are supplying sets, not only to engine shops, but to vessels where they have been found extremely useful for such things as boiler stays.

2. The ordinary fuel oil strainer containing a perforated cartridge and fine wire gauge is difficult to overhaul and clean. Imagine the job of pricking out bits of grit from a wire sieve after they have been driven in at 3,000 lb. pressure by the fuel pump of an oil engine! The serrated and grooved plug device shown in Figs. 3 and 4 was submitted to the Admiralty, who immediately gave it a trial and subsequently adopted it in submarine engines. It will be seen that the serrated plug can be withdrawn, cleaned thoroughly and put back very readily. The man who experienced this brain-wave has had no cause to regret his inspiration.

3. During a rush of condenser work it was found that progress was being delayed for lack of tube ferrules. The existing appliances for cutting the screwdriver slots were hopelessly inadequate. The foreman therefore rigged up a machine, Figs. 5 and 6, which not only saved the situation, though only working half-time, but has been adopted for other work such as cutting the slots in the turrets of castle nuts. The machine was made over to a tool maker who has already supplied several to engine builders and others.

4. Another little worry in connection with condenser production, was the time taken in cleaning the outer surface for inspection. Eleven men, working overtime, could not keep pace with requirements. The foreman in charge, who, by the way, had been through the drawing office and was an excellent draughtsman, sketched out a twin polishing machine, Fig. 7, got permission to put it in hand, and as a result two girls sufficed to replace the 11 men, Fig. 8. The foreman received a substantial reward for his resource and ingenuity.

5. The cone ends of pressure gauge pipes are sweated and brazed on to the pipe ends, and in the process become distorted. It is impossible to fair them up satisfactorily by means of a file. So an old tool-maker made a portable truing apparatus, Fig. 9, something like a small valve re-seater, and by two or three turns of the handle the correct shape of the cone is quickly

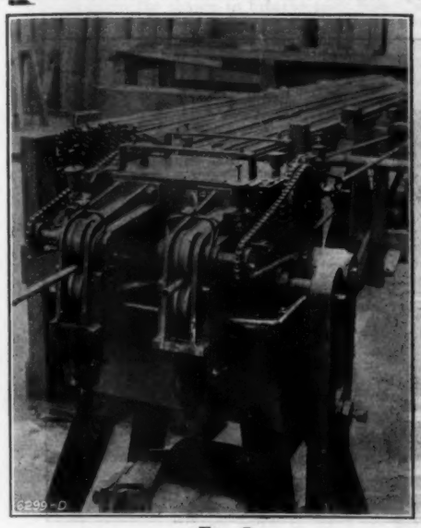


FIG. 7.

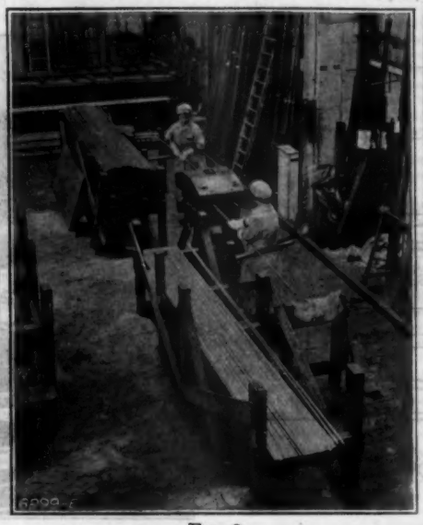
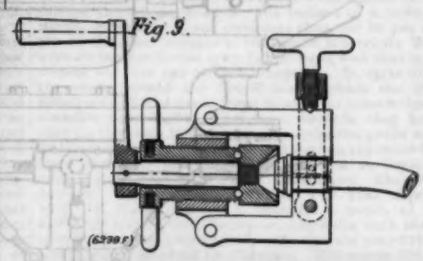


FIG. 8.

Fig. 9.



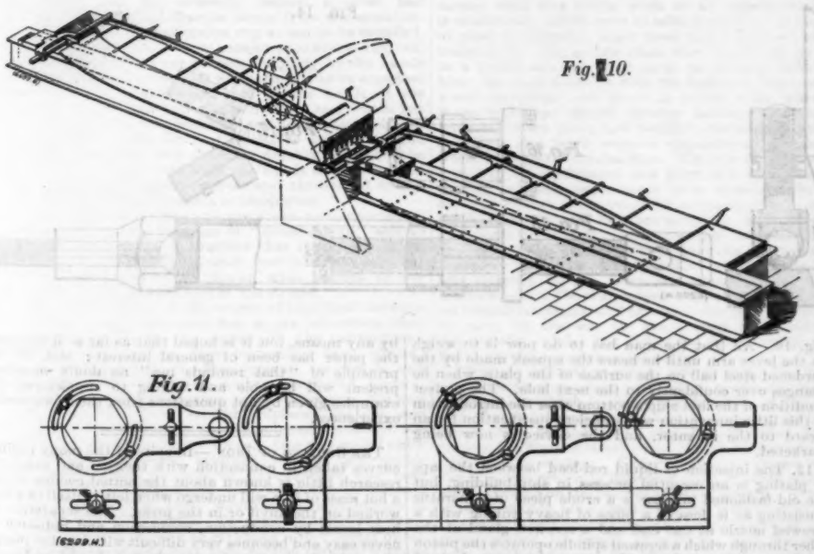


Fig. 10.

Fig. 11.

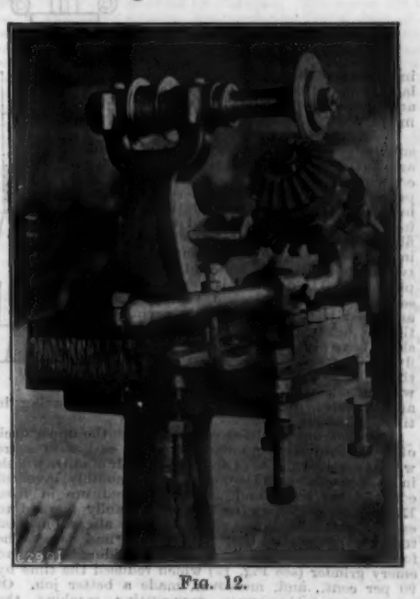


FIG. 12.

restored. It does the job first rate, and the man certainly deserved his reward.

6. The multiple punching machine for ship work is normally only suitable for rectangular plates. It occurred to one of the shipyard staff that the usefulness of the machine might be considerably enhanced if it could be adapted to punch plates whose sides were curved. By fitting adjustable curved guides to the back of the machine and devising special transverse sliding carriages to the grips at the ends of the plate, (see Fig. 10), it was found that practically all the shell plating of a vessel could be satisfactorily punched, thus saving a tremendous amount of templet work, and making a much better job. The original makers of the multiple punch acquired the patent, and are incorporating it in their new machines. And the inventor of the improvement has every reason to congratulate himself that his firm had the foresight and enterprise to father this improvement.

7. The nuts of the holding-down bolts of submarine engines, after being hardened up, are finally secured by locking plates, each covering about half-a-dozen bolts. A pattern-maker fitted a pattern over the hexagons, castings were made in the brass foundry, and then fitters had to trim and file and secure them in place. The erector in charge saw a way of eliminating the first two trades. He made an adjustable template, Fig. 11, dropped it loosely over the series of nuts to be locked, tightened it up and used it to mark off the varying position of hexagons on a thick strip of rolled sheet brass. A hexagon punch fitted to a fly-press was used to pierce the holes, and the job progressed smoothly and swiftly without enlisting the aid of pattern shop and foundry, resulting in a considerable saving in time and wages.

8. In gearing up sluice valves, &c., to the upper deck of a warship large numbers of small cast steel mitre wheels are used. The fitting of each pair of mitre wheels in its bracket so that they would gear smoothly, involved considerable time, and a large expenditure in files. Even then each pair had to be carefully marked to ensure that the same pair of teeth always meshed together, otherwise they might lock and jam. The foreman made a rough rig-up with a dividing head on an emery grinder (see Fig. 12) which reduced the time by 90 per cent., and, moreover, made a better job. Of course, as an accurate gear-cutting machine the apparatus is very imperfect, but it is quite good enough for its purpose and the resultant mitre wheel teeth are at any rate of equal thickness and equally pitched. This is a good example of doing just what is necessary and no more, for the particular class of work required.

9. It is generally admitted that test cocks on a high-pressure boiler are of little or no use, as it is difficult to determine whether steam or water is issuing. The Board of Trade rules tacitly acknowledge this and permit an extra water gauge in lieu of a set of test cocks. An engineer draughtsman engaged on boiler mountings, and who had had some awkward experiences at sea with broken gauge glasses and unreliable test cocks, conceived the idea of trying a perforated metal tube instead of a gauge glass in the extra water gauge mounting. Normally, of course, this gauge is shut off, but when required to show the water level it is operated in the usual way.

The steam jets are almost invisible, whilst the water jets show as unmistakeable white cones causing clouds of vapour. The water level is thus located to within an inch or two according to the pitch of the holes, and the gauge can then be shut off again. Representatives of the Admiralty, Board of Trade and Lloyd's have seen and approved the fitting, and it is being adopted in mercantile work. The inventor, of course, benefits accordingly.*

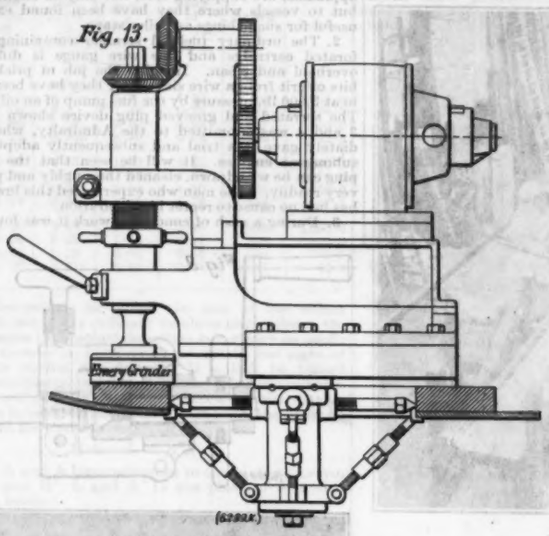
10. The facing by hand of sea-valve packing rings on the ship's skin is a long and laborious process, involving chipping, filing and scraping to a surface plate, often in a very inaccessible position. The simple grinding apparatus devised by a ship fitter and shown in Figs. 13 and 14, make a superior job in a fraction of the time previously taken.

11. Under-water shell plating is countersunk on the outside, and the rivets should just fill the countersinks and no more. The shipyard labourer who countersinks the holes operates at the end of a long spring-mounted lever and cannot conveniently see what depth he is cutting. To ensure the countersinks being of uniform depth his foreman made the simple attachment shown in Fig. 15. All that the man has to do now is to weigh on the lever arm until he hears the squeak made by the hardened steel ball on the surface of the plate, when he changes over confidently to the next hole. The perfect condition of the first ship's bottom after the introduction of this little innovation was sufficient justification for an award to the inventor, and the device is now being marketed.

12. The injection of liquid red-lead between the laps of plating is an essential process in ship-building, but the old-fashioned injector is a crude piece of apparatus consisting as it does of a piece of heavy tubing with a screwed nozzle at one end and a screwed gland at the other through which a screwed spindle operates the piston or plunger. To re-charge the pump the screwed gland is slacked back, the plunger withdrawn and the spindle screwed back to its starting point—although a messy and tedious operation. The improved pump (shown in Figs. 16, 17 and 18) was tried with success, and handed over to an outside firm in touch with shipyard work, who immediately booked more orders than they could cope with: to the advantage of the resourceful inventor.

There are many other examples that could be cited, but the dozen that have been selected will perhaps serve to show the unbounded scope that exists for such practical improvements in a typical marine engineering establishment. Sometimes, of course, one has suggestions brought forward that are manifestly impracticable or valueless, and in such cases considerable tact and patience has to be exercised so as not to discourage the would-be inventor, and above all to dispel any suspicion of favouritism. But the practical worker is generally amenable to reason, which is more than can be said for certain amateur inventors who sometimes manage to invade one's sanctum, and waste valuable time by describing some visionary scheme that is going to revolutionise the engineering world. The scheme of co-operation, however, that is outlined in this paper has the merit of inducing and inspiring that confidence between employer and employee which is one of the first essentials of real progress. It is a hopeful sign of the times; and that the principle is spreading is evidenced by the number of patents that are constantly being published under the names of prominent firms coupled with the name of "John Smith," or some otherwise obscure individual whom you may be sure is an employee of the firm.

The author was somewhat at a loss for a suitable subject when he consented to prepare a paper for this meeting, but when, in conversation with your distinguished president, he suggested its title, Lord Weir at once agreed that the subject was full of interesting possibilities. The possibilities have not been exhausted by any means, but it is hoped that as far as it has gone the paper has been of general interest; and, on the principle of "that reminds me" no doubt members present will be able and willing to supplement the examples given by apt quotations from their own varied experiences.



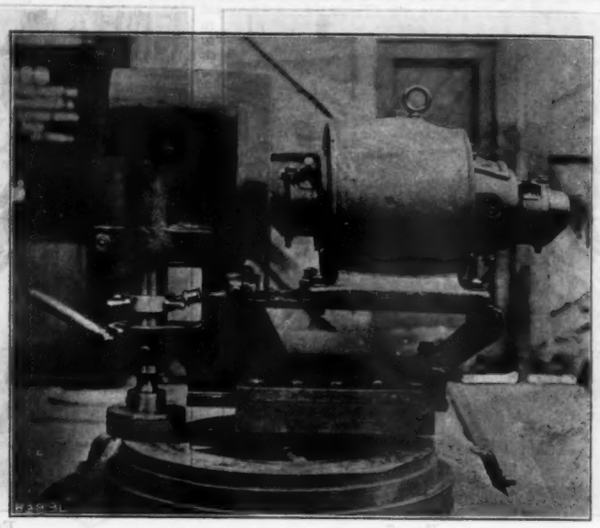
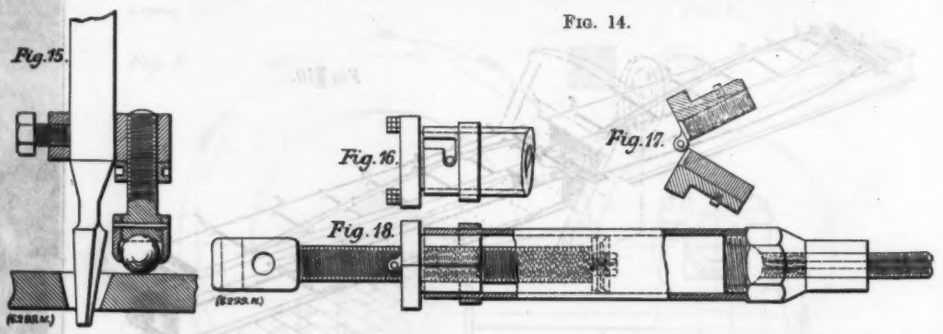


FIG. 14.



* This invention was illustrated in ENGINEERING, on page 574 *ante*.

THE COOLING OF IRON.—In spite of the many cooling curves taken in connection with thermal and magnetic research little is known about the actual cooling which a hot mass of iron will undergo when left to itself or when worked on the anvil or in the press. The separation of heat losses by conduction, convection and radiation is never easy and becomes very difficult with big, hot lumps of metal. In the experiments which F. Riedel, of Essen, described in *Stahl und Eisen*, Vol. xl., pages 1 to 9, he found that the losses by radiation can be calculated by the Stefan-Boltzmann law. For the study of radiation in particular he placed three equal test pieces (square blocks or cylinders) on top of one another, but separated them by gaps of 4 mm., so as to reduce conduction; the mild steel selected had the composition of a steel for which Oberhoffer had observed a rise of the specific heat with temperature, first regular, then abrupt between 700 deg. and 800 deg. C., to a constant value of 0·167. These specimens were heated in an electric furnace. In other experiments with slabs or discs, about 150 mm. thick and 420 mm. in length or diameter, the block was heated in a muffle furnace, then suspended free by a hook, and the thermocouples were inserted in holes previously drilled to different depths. The heat losses then observed were mainly due to radiation losses from the surface affecting the temperature distribution in the interior. More important are the heat losses by conduction when the piece worked comes in contact with the cold anvil and hammer or roll. As the piece cools, more and more energy has to be expended to obtain the same effect in compression and reduction of cross-section. Riedel considers that he can calculate the heat losses.

A GERMAN INDUSTRIALIST'S VIEWS ON SOCIALISATION.

Address to the Employees of the Allgemeine Electricitats Gesellschaft, by FELIX DEUTSCH, *Chairman of the Board of Directors.*

THE mighty socialistic wave by which everyone is affected either voluntarily or in spite of himself, springs from two principal sources. One is ethical, the other economic. I need not here enter into the ethical side of the question. It is generally acknowledged that some form of equalisation must be found between the excessive, and often enough frivolous, luxury on the one side, and a good deal of hardship on the other; that the workman must be given the chance to breathe more freely, and to obtain that share of light and sun, without which it is impossible to lead a life worth living. But it is equally clear that this ethical question can only be solved on the basis of sound and well regulated economic conditions. Idealistic phrases which often enough only hide the grossest ignorance, frivolous destruction of old economic forms without replacing them by better ones, may easily produce the effect that all riches and all luxury disappear—but it will never be possible to produce in this manner better or even more tolerable conditions of life for the great mass of the people.

During the war, which tried to the utmost the financial forces of the Empire, and has imposed upon the German people an almost unbearable burden, owing to the necessity of meeting the interest on the huge war loans, it had become clear that after the conclusion of peace, we should, in order to cover the peace budget, have to resort to means which had hitherto been practically unknown in Germany, that we, for instance, would be forced to let the Empire participate in a higher degree in the results of our economic work by the creation of monopolies. But after our internal revolution, pains-taking inquiry and conscientious discussion were replaced by the peremptory call for an immediate socialisation of public companies and great private undertakings, as well as by the demand that the State should take over all means of production. The representatives of the radical wings of the social democrats have not allowed themselves, in discussing the question, to be guided by purely economic considerations and made no inquiry as to which undertakings—if any—might, by combining them, under centralised control secure larger profits for the commonwealth and thus, be especially fitted for socialisation. The supreme power in the State having fallen into the hands of the labouring classes, they considered that the ardently desired moment had arrived, when the old Marxist demand for the socialisation of all means of production was at last to be satisfied, the capitalistic form of social economy for ever destroyed, and all economic power placed definitely in the hands of the manual labourers. It was naturally to be expected that this idea, which took root in the heads of the socialists more than half a century ago, and which has become one of the most essential articles in their political creed, would, under the new *regime* be quickly pressed towards realisation, and the more quickly, the more the leadership was snatched from the hands of level-headed and experienced representatives and threatened to fall into those of radical idealists or ideologues.

I shall now try to give you my views and experiences with regard to this question of "socialisation" and to show you in how far I consider that it is practicable, how far I consider it has already been effected and what are the inferences to be drawn with respect to our situation in the present and in the future.

For the first time, in the course of historical development a new economic order has, at one fell swoop, been brought into being by order of the authorities. Hitherto such changes have invariably been effected by a long process of development, by which one order has been destroyed and a new one formed. However great the difference between the two, the new form has almost imperceptibly replaced the old, and by but very slow degrees have men become aware of the revolution which has taken place. Our new social order would also have been attained without perceptible convulsions, had its natural development not been interfered with. The State, such as it was constituted up to November 9, 1918, would have been unable to impede this development. To preserve itself the State would have been forced to establish a new social order, but the change would have been carried through without painful operations and without shaking our economic life. Now, that the attempt is made to decree this new order before our economic life has become mature for it, resistance is, as a matter of course, provoked, and success endangered. It is always much easier to *proclaim* an idea than to *realise* it. At any rate the sudden and unprepared transition from capitalism to socialism cannot be nearly so easily carried through as the change from a monarchy to a republic. Socialists are fond of quoting the sentence "revolutions are not made, they break out spontaneously whenever the conditions for them are in existence." I wonder whether this truth does not refer equally as well to the economic as to the political field.

When we consider the possibility of a radical socialisation we must first of all not forget the fact that all these fanciful pictures are based on the false assumption that the human material indispensable for the realisation of such plans, is full of an unshakeable idealism and of the very highest public spirit. Our latest experiences may possibly teach us to judge men more carefully and more objectively and not to place too great a confidence in their altruism; so long as men remain such as they are, so long will it be prudent to see in their self-interest, in their egotism, one of the most important, if not the only decisive economic incentive. Unless this incentive co-operates, there is no longer any guarantee for the stability of the national economy. The socialists should be reminded of the words of one of their most highly esteemed leaders, August Bebel, whose authority is still acknowledged by them; "Where there is not profit, the chimneys don't smoke!" Even in a socialist state, in socialised industry the chimneys will stop smoking, if no profit, no economic result can be obtained; for no undertaking can exist without being assured of lasting profitable results and when calculating these, the risk to be run must also be taken into account.

When we consider the wonderful rise of the German industry during the last few decades, which is practically unequalled in history, we are faced by the question whether such developments would have been equally possible under a socialist organisation of our economic life. What was the basis of this progress, the rate of which was unequalled in the old, as well as the new world? It was based on the scientific methods of our industrialisation, on an organisation and administration efficiently carried through in factory and office, on conscientious study and utilisation of all technical progress and experience in the whole world, on the keenest and unremitting observation of all happenings which might occur industrially and commercially, not only at home but also abroad, on the minutest knowledge of all possibilities of sale in the different markets, and finally on a highly educated staff of employees, and a most efficient labouring population. By these means we attained an industrial position, admired even by those countries which were our keenest competitors. For a long time before the war our German methods were the object of the most careful study on the part of foreign countries and were imitated by them.

Could we really have achieved all this if the self-interest of the economic personality had been eliminated and our industry had been socialistically organised? Even when recognising to the full the excellent moral qualities of our state employees, their fidelity and conscientiousness, their all-round education and true devotion to their duty, this question must be answered in the negative. For, if we consider the organisation of our bureaucratic system and the position, which is given to the individual within that system—and herein nothing essential can be changed even within a socialistic commonwealth—even if the higher bureaucracy is no longer forced to recruit itself from those classes which have passed through two law examinations, it is impossible to suppose that the State employees can have that measure of initiative and force of decision without which the private business man cannot exist and cannot achieve success. Whoever must run risks, such as are indissolubly connected with the whole work of an industrialist, who is continually called upon to take quickly novel decisions of great importance, must have had a different kind of training for this calling than that which can be given to a public servant. He must psychically differ from him; he must combine with the feeling of responsibility a self-confidence and pluck in taking risks, which the State employee cannot develop because it is not his business to act freely and without consultation with his superiors and with cognate departments in matters, which involve a financial risk. The fear of unfavourable criticism by Parliament and press will be sufficient to prevent a State department from spending the large amounts, which are continually indispensable for experiments, patents and new installations, more especially since such expenditure is frequently not accompanied by any immediate profit. These qualities of our leading men were one of the principal factors which have raised our industry to the great importance, which it had reached before the war, which was admired and envied by foreign countries, and by which Germany was enabled to carry on the war for years, both technically and industrially, whilst the industrial undertakings of the State proved a complete failure.

There is a further point, which gives the private undertaking a stronger position as compared with the undertaking which is under the direction of the State, and that is its greater freedom in granting higher remuneration to specially capable employees. In this respect the State is strictly bound both by legal prescription and by custom. Every office is endowed with a fixed salary, which is increased only by such additions as are granted on the basis of length of service. Increases of salaries only take place when the individual is raised to a higher position, and these higher positions are usually only reached by length of service. This custom was only deviated from in the filling up of leading positions, but in these cases it was not always for greater capacity, but for very different qualities, which had nothing to do with better qualification for a higher office, that an exception was made to the rule. Such conditions cannot and must not influence a private undertaking, which is making a continuous fight with competitors at home and abroad. If it desires to remain successful, it must, in selecting its leaders and employees, be solely guided by their capabilities. It can reward the capable by higher salaries, and it can give him a participation in the profits according to his merits. The capable man has "an open field before him" and carries his Marshal's baton in his knapsack.

The experience, which we have hitherto had with concerns taken over by the State or by municipalities are not of a kind to encourage the continuation of such attempts. On the contrary they prove how little these concerns are able to stand competition with private undertakings. In fact, up to now the State when acquiring private concerns has generally not permitted itself to be guided by fiscal considerations, but only by the wish to obtain the full and unlimited power over certain concerns—like railways—which appear to be indispensable for military or economic ends. In the case of the coal mines, which the Prussian State possesses in Upper Silesia, Westphalia and in the Saar Valley, the result of State management has been that the profit has hardly amounted to 1 per cent. of the capital employed, whilst private companies pay dividends of 10 per cent. and more! This is only a fresh confirmation of previous experience that State administration is more expensive than private administration, and may as is proved by results of State coal-mining, be very considerably more expensive. Under these circumstances one must wonder why the State did not let its mines on lease and obtain thereby a fixed percentage for the capital employed. This would certainly have been more profitable to the State and more acceptable to the tax-payer.

Let us take another case, which is nearer to us. The Berlin Electricity Works distributed in the years 1910–14 to their shareholders annually 6,192,000 marks. They paid to the town as their share of the profits between 3,500,000 marks and 4,000,000 marks—and, further, they paid in taxes on gross receipts 2,798,704 marks, 3,035,354 marks, 3,263,691 marks, and 3,400,011 marks respectively.

We thus see that the town of Berlin obtained from the Berlin Electricity Works up to the outbreak of the war, in rates and share of profits, an amount which increased from year to year, and had risen in the year ending on June 30, 1914, to over 7,000,000 marks, and which exceeded by more than 1,000,000 marks the dividends paid for that year to the shareholders.

One would suppose that the town had no reason to wish for a change from this state of affairs which gave it, without risk or trouble, a revenue which must be considered important, even for the budget of a town like Berlin, especially if one considers that the 10 per cent. tax on the gross receipts of the Berlin Electricity Works were an income to the town in any case, and that in this respect the city ran no risk whatever. In spite of this the town refused the liberal offers which the Berlin Electricity Works made them in order to induce them to abandon their right of purchase, because they hoped, that by the town taking over the works the profit would on the one hand be increased, and that on the other hand they would at the same time be able to lower the price of electric current to consumers. This hope, however, has not been fulfilled. The year, April 1, 1916, to March 31, 1917, brought a profit of only 4,681,835 marks, and the report concludes with the sad remark that it was doubtful whether for the year 1917–18 any profit at all could be obtained. The report 1917–18 is not yet available, but probably the author of the report has proved a true prophet and after the enormous increases of wages which have been forced through during the last strike, the hope of a profit from these works has still further decreased. This socialisation has, therefore, up to the present not been a pleasant experience for the inhabitants of Berlin, for it has not only led to a considerable further burdening of the town budget, but it has also led to an increase in the budget of every individual by the repeated raising of the tariffs for light and power. Even taking account of the fact that the situation during the war has been less favourable, the town could under the former arrangement not have sustained any loss, and they would at any rate have obtained the 10 per cent. tax on the gross receipts. The company, too, would have worked less favourably, but the community would not have been called upon to make good these losses in the form of higher taxation.

The above-mentioned strike in the City of Berlin's Electric Works proves, by the way, as one of the Berlin newspapers justly remarked, that the workmen are not by any means restrained from doing the most serious damage even to public undertakings, and that it is a grave illusion to suppose that the socialisation of great industrial concerns would guarantee favourable developments on the hypothesis that the class egotism of the working men would call a halt before it would hamper socialised undertakings.

Further examples illustrating the purposelessness and the bad yield obtained from State or municipal concerns could easily be given. It is nearly always possible to prove that these experiences are due to the vanity of individuals, to their devotion to theories or to their lack of business experience, by which what should be great surpluses are converted into deficits, which the taxpayer has to make good!

But the most serious aspect of the question of socialisation becomes apparent, when it is intended to include those industries which are organised for export to foreign countries—and between 33⅓ per cent. and 40 per cent. of the whole turnover of the German industries was, until the outbreak of the war, exported to foreign countries.

A State department would be quite incapable of taking over this part of the task of a private concern: for the basic conditions of this class of business are not only a knowledge of foreign languages, but also a knowledge of foreign countries and peoples, and of the industrial financial and business conditions of each country and its inhabitants. The qualifications further include a sure judgment as to the requirements and the taste of each people, as well as to the solvency of each customer—qualifications not to be expected from a State employee.

There are, however, certain types of business, which can be taken over by the State without any further preliminaries.

It is quite feasible to place the large forests, as well as turf moors and similar property under State administration; the state can also take over all monopolised manufactures such as aluminium factories, nitrogen works, water power installations, in which the state possesses even now a considerable participation. Cigars and cigarettes, alcohol, petrol and similar monopolies are equally possible, also installation for public transport in large towns, such as have been carried out with the co-operation of our own firm at Hamburg.

There is also a good deal of talk nowadays about the

socialisation of great electrical power installations. This is not new to us. You all know that we have foreseen for many years past that a moment must come when—for a variety of reasons, such as delimitation of provinces and communalities, which include difficult questions of rights of way, &c., the authorities would have to take into their own hands the production of power by large plants, and we have ourselves initiated quite a number of combinations of this description. I need only mention the Maerkisch Elektricitäts-Werke, which we manage jointly with the province of Brandenburg and the large works of the Elektricitäts-Lieferungs-Gesellschaft, in Saxony, which have been sold to the State, &c., &c.

Yet, in the case of all technical and industrial concerns a mixed system (State and private combined) would, in my opinion be preferable, in order to secure the technical and commercial knowledge and experience of the former owners; for even in such concerns the "technic" is not definitely fixed and has not come to a standstill, and if one does not wish to hurt one's own country compared with foreign countries by too high prices of monopolised commodities, it will be indispensable to make every effort to remain on the highest level as regards scientific and technical development, otherwise we may easily lose many times over in other directions all the profit nominally made by the State out of these monopolies.

Thus, I am of opinion that a number of concerns may, with care, be socialised, but that a radical socialisation, that is to say a taking over of all means of production by the State would, in the majority of cases, seriously jeopardise their profitableness, and would, for the commonwealth not only not result in a benefit, but would mean a financial burden, to which in the end every individual would have to contribute.

How has it, then, happened that the term of "socialisation" has been inculcated with such ineradicable tenacity into millions of brains, and that more especially the working classes see in it a panacea, which is destined to do away, once for all, with all their troubles, and with all dissatisfaction with their economic position.

The dissatisfaction, the enmity of the working man against the system of capitalistic production receives an ever-renewed incentive from the belief that a small number of capitalists grasp by far and away largest part of the profit produced by the industrial labour, whilst the labouring classes must content themselves with a very small share of these profits.

The idea is as false as it is inciting and, as long as one does not succeed in convincing the labouring man of the real facts, a fruitful and peaceful co-operation of the two factors of economic production remains in the long run impossible.

It is not difficult to prove the fallacy of the whole idea, and especially to show, that the contention that one-tenth of the population—the capitalists—obtain two-thirds of the industrial income, whilst the other nine-tenths—the working man—have to be content with the remaining one-third, is utterly at variance with the actual facts.

This contention is already confuted by reference to the quotations of the Berlin Stock Exchange, according to which the average yield of all shares does not amount to more than 6 per cent., although only well financed and carefully conducted concerns are admitted to an official quotation.

But if we go one step further and proceed to study the situation of the greatest and most stable industrial companies, we obtain the following picture:—

The average dividend of a large number of concerns, the situation of which forms the basis of my observations, has, during the last ten years, amounted to 10 per cent. Hence, since the shareholder of these companies has, in view of the rate of interest, had to pay at least 200 per cent.—and in many cases considerably more—for his share, he obtains in reality a yield of only 5 per cent. for his investment.

Since it is easy to buy State securities with a fixed yield of 5 per cent. the capitalist does not obtain any additional yield as an offset against the risk of all dividend fluctuations, caused by politics, competition, speculation or any unfavourable concourse of circumstances, one might wonder why the capitalist invests his money in industrial concerns, were it not well known that speculation, the possible chance of making a profit on the price of the shares in a rising market, has for many people a considerable attraction.

But the hollowness of all this talk of exploitation can only be seen by trying to fix the proportion in which wages and salaries paid by the companies to their workmen and employees, as well as in State, communal and social taxation, stand to the amounts paid in dividends.

These details are not easily obtainable; they are seldom to be found in business reports and other publications, for a very good reason. The companies, in as far as their organisations are at all in a position to furnish these statistical details, are not inclined to publish such data, which are very confidential, and at the same time would convey very important information to their competitors.

In spite of this I have succeeded in the common interest, and for the information of all interested parties in obtaining from a number of companies—as a matter of fact, from 66—which represent different industries in all parts of Germany (mines, foundries, engine factories, electrotechnical undertakings, shipbuilding yards, motor-car factories and other) the necessary details, the analysis of which yields the following figures—naturally without mentioning any names.

The 66 companies have at present a total capital of about 2·5 milliard marks and have, as already mentioned, paid on an average a yearly dividend of 10 per cent.—that means they stand considerably above the average yield of the Berlin Stock Exchange list.

The total amount of the dividends paid by them on an average during the last ten years was 215,220,000 marks.

It appears, further, that during ten years, wages and salaries paid have amounted to 1,424,800,000 marks annually, whilst taxes, insurances and social purposes absorbed 217,160,000 marks annually.

The dividends have thus amounted to only 13 per cent. of these two sums, or, in other words, of every mark spent there has been paid to—

	Pfennig.
Employees and workmen	76·7
State, municipalities	11·7
Shareholders	11·6

It must also not be overlooked that many companies have obtained considerable amounts in the nature of dividends from associated companies, and from foreign countries, for which the workmen have not done any work, and to which they have in no way contributed.

A further calculation will make this situation still clearer.

These companies have, as explained, divided during the last ten years a yearly average of 215,000,000 marks in dividends, and at the same time employed 783,781 employees and workmen.

Supposing for a moment that the shareholders were all idealists and renounced all claims to a return on their capital in favour of the workmen and employees, what would be the result.

Even in these exceptionally well-paying enterprises an amount of 11 pfennigs per head an hour would be earned, that is 270 marks per year per head!

It may be noted that in the "Zeiss" concern the situation is of a similar nature.

Professor Abbe, who, on the death of Carl Zeiss, became the sole proprietor of the works, in the year 1891 ceded his property to the "Carl Zeiss Institution" created by himself.

The Articles of Association described the object of the Institution as follows:—

"Besides the general and scientific objects of the Institution it is intended to serve the purpose of fulfilling social duties on a larger scale than personal proprietors might be expected definitely to undertake."

Thus the capital of the Institution, which is administered impersonally by a commission chosen by the State, the university and the municipality, obtains only 5 per cent. interest, whilst the surplus profit, after endowing a number of different funds, is divided among the employees and workmen in the form of additional payment in salaries and wages.

The negotiations to settle the Articles of Association lasted for several years; the new organisation only came into operation in the year 1896. From that moment—a period of over twenty years—the yearly additional payment has never amounted to more than 150 marks to 200 marks per head—one year, indeed, there was no additional payment possible—in spite of the fact that salaries and wages in Jena have always been considerably below the standard of larger industrial centres.

These figures are practically identical with those I have given above.

A third example leads to the same conclusion. The statistics of the Union for the mining industry at Essen give the following figures.

The district employed on an average during the last ten years 439,000 employees and labourers.

The total sum of salaries and wages paid to them amounted on a yearly average to 870,000,000 marks. Taxes for State and municipalities, and contributions for social purposes, amounted to 73,000,000 marks; and dividends amounted to 106,000,000 marks.

The yield to capital amounts, therefore, to 11 per cent. of the first two amounts, and if the whole of the dividend had been distributed among the employees and workmen the addition would have been but 240 marks per head.

It is clear that all calculations must lead to similar results—for the share of the capital in the profits is really very small; it must be mentioned especially that all the figures given are for periods concluding at the end of December, 1917, or end of June, 1918. A summary, when made up for the year 1918–19, must inevitably show a reduction of the proportion of dividends to salaries and wages, since the latter have experienced enormous increases since the month of November, 1918.

(To be continued.)

THE SWISS TECHNICAL HIGH SCHOOL AND THE ALUMINIUM WORKS, NEUHAUSEN.—When it became clear during the latter stages of the war that the conclusion of peace would leave a neutral country like Switzerland economically in a serious condition, the G.E.P., the association of former students of the Zürich Polytechnic, which years ago adopted the name "Eidgenössische Technische Hochschule E.T.H." (Federal Technical High School), took the initiative in the creation of a Fund for the Promotion of Swiss National Economy by Scientific Research at the E.T.H. Independent of these efforts the Aluminium Industrie Gesellschaft Neuhausen resolved in 1918 to place the sum of 500,000 francs at the disposal of the High School, especially for the promotion of research in the field of applied electricity. The donation was accepted by the Swiss Federal Council, and the rules under which the "Aluminium-Fonds Neuhausen" is to be administered were published in the *Schweizerische Bauzeitung* of May 1 last. It is understood that research on electrometallurgy and electrochemistry is to be favoured. The donation was made in connection with the thirtieth anniversary of the establishment of the Neuhausen company.

CATALOGUES.

Steam Hammers.—A new edition of their steam hammer catalogue comes from Messrs. B. and S. Massey, Limited, Openshaw, Manchester. The pedestal, or overhung, type and the arch and girder types for general forging, are all represented, as well as a number of hammers specially adapted for particular work. A very large range of sizes is made in all cases, and all necessary weights and dimensions are given in the catalogue; some useful practical information is also included.

Hoisting Machinery.—The Vaughan Crane Company, Limited, of Openshaw, Manchester, send a new edition of their catalogue—a well-printed and bound book of 100 pages. The products are essentially a hand-operated hoisting block and power-driven developments of it. These are adapted to all kinds of situations and purposes, from a vertical lift to an extended travel of the load. Only electric power is employed, and separate motors are fitted to operate the hoisting, the cross-travel and the longitudinal movements.

Water Current Meter.—A new recording water current meter is described in a four-page pamphlet from Messrs. T. Cooke and Sons, Limited, 3, Broadway, Westminster, London, S.W. 1. It is intended for general use, short of very precise measurement, and may be used clamped to a pole or tube, or suspended from cables. The standard propeller gives direct records accurate to within 2 per cent. for medium velocities. Very low velocities may be measured with the correction scale or a special propeller. The catalogue gives full directions for use and cleaning.

Switch Gear.—Catalogues dealing with several types of switch gear, received from the Metropolitan Vickers Electrical Company, Limited, of Manchester, include one dealing with a truck type for high-tension and low-tension circuits, which is particularly suitable for use where space is limited. Others are devoted to an oil-break pillar for alternating-current circuits up to 650 volts, a flexible unit-type control gear for making up a distribution board for ships, and some special oil switches. All the catalogues are illustrated and contain brief and clear descriptive text.

Electric Power Lines.—A book of 80 pages quarto, issued by Messrs. Johnson and Phillips, Limited, of Charlton, London, S.E. 7, is devoted to the subject of overhead electric power transmission lines. It deals exhaustively with the materials, methods of construction and maintenance of long-distance lines, in view of the proposal to concentrate the production of current near collieries and natural water power. Many useful tables and much technical information are given, and also explanations of the legal requirements to be fulfilled in erecting and operating such lines. The firm will send copies of the book at a charge of 10*s.* 6*d.* each.

Gas Furnaces.—Chantraine's method of filling a space with gas and making it burn by forcing jets of hot air into it is explained in a catalogue issued by Smeeton-Wright Furnaces, Limited, of 56, Victoria-street, London, S.W. 1, who are the sole licensees and manufacturers for this country and the Colonies. The furnaces shown in the catalogue include cells or pot holes in which crucibles are placed, continuous furnaces for re-heating slabs, billets and ingots, single and double puddling furnaces, continuous tube and bar reheating furnaces, heavy plate furnaces, pot annealing furnaces, soaking pits, &c. Economy in fuel and wear of furnace fittings is claimed on grounds that are worth careful consideration.

Road Rollers.—Messrs. Marshall, Sons and Co., Limited, of Gainsborough, send a new edition of their catalogue of steam road rollers which are now in great demand. They are made in five standard sizes, of which the nominal weights (empty) are 6 tons, 8 tons, 10 tons, 12 tons and 14 tons. All sizes are made with single cylinders or of the compound type. Heavier sizes are made to order, but are not extensively used. The working weights add from 1 ton to 2 tons to the nominal weights stated. In many cases these engines are supplied with a set of traction wheels, and a bonnet, for conversion to traction engines, an economical arrangement where the year's work can be divided into rolling seasons and stone hauling seasons. Winding drums for steam ploughing, scarifiers for breaking up old road surfaces, water-spraying apparatus, &c., are fitted as required. Tenders, wagons, living and sleeping vans, are also supplied. In some cases the engines are provided with large fire-boxes for burning wood, and in other cases oil-burning apparatus is fitted.

REFINING LOW CARBON BASIC STEEL.—A method of refining basic low-carbon steel forms the subject of a patent (U.S. 1,309,162) granted to William R. Walker, assistant to the president of the United States Steel Corporation, says *The Iron Age*, New York. The method involves maintaining the metal in the ladle at a proper pouring temperature for a sufficient time to degasify the melt and yet under a slag so modified that re-phosphorisation will not result. Thus, when the open-hearth furnace is tapped the metal runs into a ladle of such size that most of the slag overflows. The remainder may be skimmed mechanically, and replaced by a molten phosphorus-free slag, or if the furnace slag be low in phosphorus, lime may be added in the runner so that it is intimately mixed with that portion of the slag remaining in the ladle, thus increasing its viscosity and consequently decreasing the rephosphorising action at the surface of the metal. During the time the metal is in the ladle it is kept hot, preferably by electrical currents induced by a high-frequency coil placed about the ladle.